THE

GEOLOGICAL MAGAZINE

NEW SERIES. DECADE VI. VOL. III.

No. X.—OCTOBER, 1916.

ORIGINAL ARTICLES.

I.—Notes on new or imperfectly known Chalk Polyzoa.

By R. M. Brydone, F.G.S.

(*Continued from the August Number, p. 339.*)

(PLATE XVIII.)

CHEILOSTOMATOUS Polyzoa are anything but common in the Chalk exposed on the Norfolk coast between Cromer and Weybourne, and which I will call the Weybourne Chalk as it is best exposed in the Weybourne half of the area. It was only quite recently that I realized that the gradual accumulation of material had produced a sufficient volume to give some idea of the general nature of the fauna. The precise position of this chalk in the zone of *B. mucronata* cannot be fixed on physical data, but the Survey view that it is only a little way below the Trimingham Chalk is highly probable. It is therefore rather remarkable to find that the *Membraniporæ* include several new species, in addition to *M. flacilla* (*ante*, p. 338), which are unknown so far at Trimingham. It will be interesting to see if these, which I proceed to describe, prove to be characteristic of any definite range of chalk in the Norfolk Senonian. They must all be described as scarce at Weybourne.

Membranipora fluonia, sp. nov. (Pl. XVIII, Figs. 1 and 2.)

Zoarium unilaminate, adherent.

Zoœcia strongly pyriporiform, very large; ·9 mm. is an average length in the centre of the zoarium, and the marginal zoœcia frequently run to such lengths as 1·2 mm.: areas on the whole broadly elliptical, but varying from broadly oval to practically circular, with lengths varying from an average of ·45 mm. in the centre of the zoarium up to ·6 mm. at the margin; they occupy the bottom of cups formed by the internal front walls, which are of considerable width, and have a markedly prismatic structure, and are separated from the convex external front walls by a ridge which though obtuse-angled is often quite sharp.

Oœcia prominent, sub-conical, with a slightly contracted base; free edge moderately concave.

Avicularia sub-vicarious, initiating new rows of zoœcia, large and of hour-glass type with remains of a crossbar well below the region of constriction, and the area narrowly lancet-shaped at the upper end.

MEMBRANIPORA FONTEIA, sp. nov. (Pl. XVIII, Figs. 3 and 4.)

Zoarium unilaminate, adherent.

Zoœcia fairly large, with a tendency to angular sides, bluntly pyriporiform when occurring in established lines, and acutely so when initiating new lines; areas typically oval, with the upper end generally flattened and often indented, average length ·5 mm., breadth ·35 mm.

Oœcia globular, rather elongated, with a deeply concave free edge; aperture high and narrow.

Avicularia sub-vicarious, initiating new rows of zoœcia, mandibular in type, much inflated laterally.

MEMBRANIPORA CUBITALIS, sp. nov. (Pl. XVIII, Fig. 5.)

Zoarium unilaminate, adherent.

Zoœcia sub-pyriporiform, fairly large, very variable in dimensions, unusually wide, sometimes much wider than long, with sharply angular elbow-like sides; areas widely oval, flattened at the upper end, average length ·45 mm., breadth ·4 mm., front walls almost flat.

Oœcia abundant, short wide inconspicuous swellings, the free edges of which coincide with the areal outline.

Avicularia vicarious, of the '*Lesueuri*' type, but unusually wide and short, and with the nodal points close to the upper end of the area; they are so nearly identical in size with the zoœcia and the nodal points impinge so slightly on the areal outline that it is very difficult to pick them out (there are three in Fig. 5), but a side light will catch the upturned edge of the infold of the side wall and make it stand out against the deep-lying internal front wall.

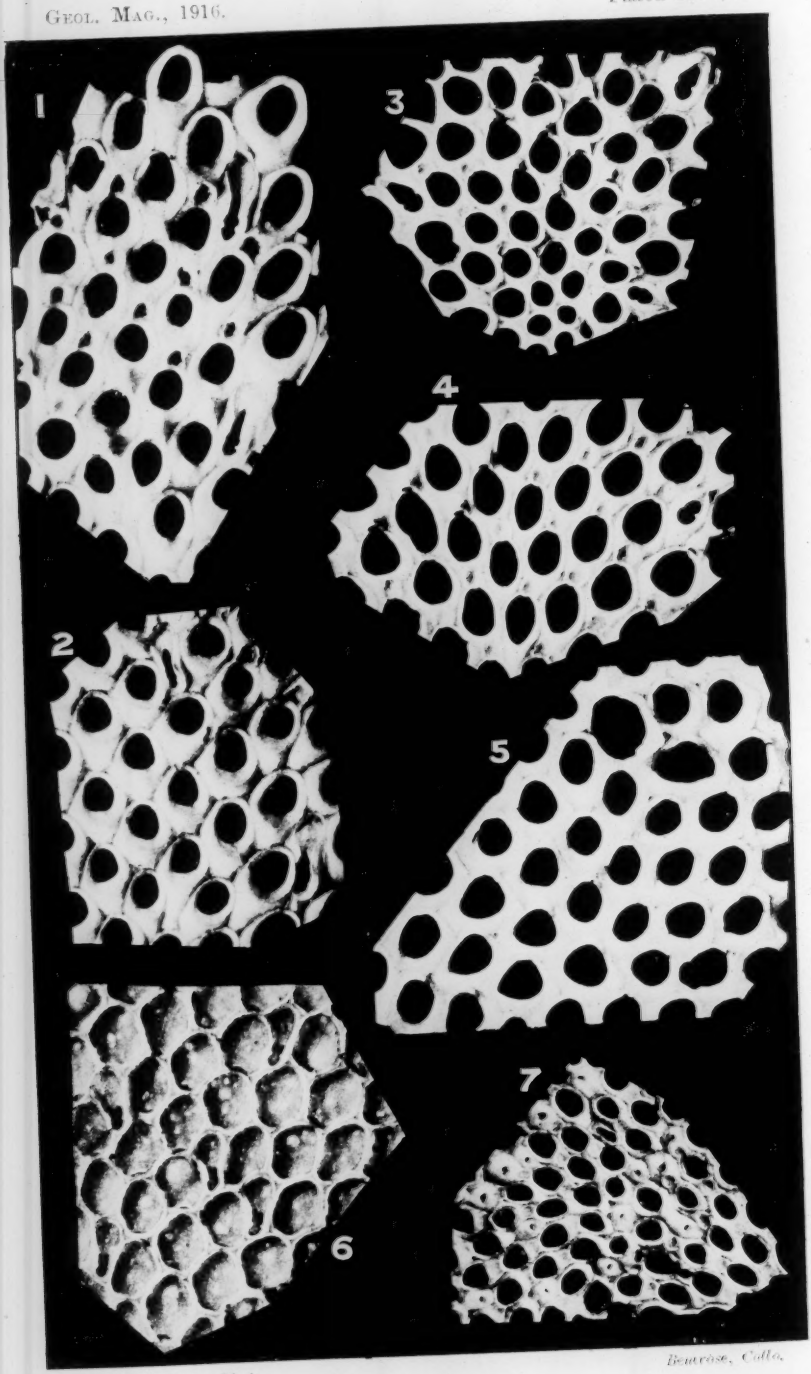
MEMBRANIPORA FULGORA, sp. nov. (Pl. XVIII, Fig. 6.)

Zoarium unilaminate, adherent.

Zoœcia large, very shallow, with very thin side walls and no front walls at all, which gives them a very primitive aspect; average length of areas ·65 mm., breadth ·5 mm.; at the foot of the area there occurs very regularly a crescent-shaped cavity in the floor, round which the floor is slightly raised and which may be oœcial; the side walls tend to expand at the bottom, and the curved part is here and there pierced by pores, which probably occur regularly though only visible irregularly.

There are no signs of external oœcia.

Avicularia sub-vicarious, initiating new rows of zoœcia, of the hour-glass type, but hardly expanding at all below the contracted region, while above the contracted region there is a widely expanded part taking up about half the total length; the front wall is reduced to a minimum, and they are practically all side wall and area; in the lower two-fifths of the area the floor is at a lower level than in the upper three-fifths, and from the centre of the edge of the upper floor a narrow tongue runs down to the lower floor; remains of a crossbar occur at the lower end of the constricted region. This species has an interesting *general* resemblance to *M. faustina* (*ante*, p. 337).



R. M. Brydone, Photo. Beauvais, Calto.

Chalk Polyzoa.

MEMBRANIPORA FURINA, sp. nov. (Pl. XVIII, Fig. 7.)

Zoarium unilaminate, adherent.

Zoœcia small, pyriporiform whenever they are not called upon to support an oœcium for a preceding zoœcium; areas elliptical, average length ·32 mm., breadth ·2 mm.; many of the zoœcia are closed by a slightly convex lid, in the centre of which, in a small depression, there is a tiny semicircular aperture surrounded by a faint rim; it is of course possible that these are not zoœcia but avicularia, but I prefer to regard the lids as analogous to those of *Escharina* (?) *intricata*, Lonsdale,[1] especially as they occur freely in established lines of zoœcia.

Oœcia abundant, ground-plan semicircular (no perfect specimen yet found).

Avicularia very scarce, small sub-vicarious examples of the simple hour-glass type.

This species is *relatively* abundant.

EXPLANATION OF PLATE XVIII.

(All figures × 12 diams. All figured specimens from Weybourne.)

FIG.

1, 2. *Membranipora fluonia*, sp. nov.
3, 4. *M. fonteia*, sp. nov.
5. *M. cubitalis*, sp. nov.
6. *M. fulgora*, sp. nov.
7. *M. furina*, sp. nov.

(*To be continued.*)

II.—FURTHER NOTES ON THE PETROGRAPHY OF SOUTH GEORGIA.

By G. W. TYRRELL, A.R.C.Sc., F.G.S., Lecturer in Geology, Glasgow University.

THE new material on which this paper is based has lately been received through Mr. D. Ferguson, who recently investigated the geology of the island, and collected the rocks described in an earlier paper.[2] It consists of twenty-seven rock specimens from the south-eastern end of the island, between Cape Disappointment and Cooper Island, and nine specimens from Gold Harbour on the north-east coast between Cooper Island and Royal Bay. All these were collected by the staff of the South Georgia Co., Ltd., under the instructions of Mr. Th. E. Salvesen, managing director, of Leith.

Furthermore, by the kindness of Professor L. V. Pirsson, of the Sheffield Scientific School, Yale University, I have been enabled to examine a few beach pebbles collected from South Georgia in 1871 by R. W. Chappell, a whaling captain. These consist mainly of slates and phyllites, with sheared, faulted, and quartz-veined greywackes, probably belonging to the Lower Division of the Cumberland Bay Series. There is also a rounded pebble of a fresh vesicular lava of unusual composition which is described later in this paper.

[1] Dixon's *Geology of Sussex*, p. 316, pl. xviii B, figs. 8, 8*a*, 8*b*.

[2] GEOL. MAG., Dec. VI, Vol. I, pp. 53–64, 1914; Trans. Roy. Soc. Edinburgh, vol. l, pt. iv, pp. 797–836, 1915.

The sedimentary rocks in Mr. Ferguson's collection are as follows: Between Slosarczyk Bay and Cape Disappointment there are found siliceous slates, and phyllites with vein-quartz and lenticles of crystalline limestone, in all respects similar to the types found in the Lower Division of the Cumberland Bay Series. Phyllites with quartz veins also occur on Cooper Island. In Slosarczyk Bay occurs a hornfelsed shale with peculiar clots of epidote, which is clearly associated with the epidotized rocks described later.

The Gold Harbour rocks are mainly sedimentary and are of some interest. There is a hard, green, quartzitic arkose, composed of extremely angular grains of quartz and felspar in about equal quantities. The felspar is mainly microperthitic orthoclase, with some microcline, and varies considerably in freshness, but the turbid altered fragments are dominant. There is a little scattered chlorite, and some fine-textured siliceous matter which acts as cement. The rock is clearly an arkose derived immediately from a granite. It is entirely unsheared, and its interest lies in the fact that it supplies an original material for the puzzling "sheared felspathic grits", "augen-grits", and "porphyroids" (Nordenskjöld) described in the earlier paper.[1] Several of these rocks occur in Gold Harbour. Their mineral composition is identical with that of the arkose described above; but the quartz has been crushed down to a fine-grained granulitic paste, which forms the groundmass to numerous augen of felspar. The latter are outlined by dark, indefinite, wavy lines, consisting mainly of greenish micaceous material. Recrystallization has begun in the rock, resulting in the production of innumerable flakes of sericite interpenetrating with the quartz of the groundmass.

Two specimens from Gold Harbour are probably sheared acid tuffs, somewhat similar to those described in the earlier paper.[2] They are hard to separate from the sheared grits, but the augen texture is not so well developed, quartz is much less abundant, and the felspar has frequently not been aligned with the foliation. One of the rocks approaches a slate in appearance. The cleavage is interrupted by numerous augen of fresh orthoclase, and a few of oligoclase; and also by a few rock fragments, one of which is clearly a trachyte. This rock is therefore close to the trachytic tuffs described previously, although it appears to contain more sedimentary material than they. Finally a phyllite interbedded with grits, and a coarse conglomeratic quartzite rock impregnated with pyrrhotite, may be noticed from Gold Harbour. The latter rock contains a large quantity of chlorite interleaved with brown biotite, and has the appearance of having suffered thermal metamorphism. All the above-described rocks probably belong to the Lower Division of the Cumberland Bay Series.

The igneous rocks may be classified as follows: (1) Epidiorite; (2) Ophitic dolerite and basalt; (3) Alaskite; (4) Quartz-felsite, with spherulitic and non-spherulitic varieties; (5) Lavas and tuffaceous rocks of doubtful affinities, and epidosite; (6) Augitite.

[1] Tyrrell, "The Petrology of S. Georgia": Trans. Roy. Soc. Edinburgh, vol. l, p. 825, 1915.
[2] Ibid., p. 827.

1. *Epidiorite* (*Meta-dolerite*).—This is a medium-grained greenish rock occurring in Gold Harbour. In thin section it shows large irregular plates of a pale hornblende in ophitic relations with numerous small laths of labradorite. There is a quantity of interstitial, probably secondary, quartz and leucoxenic material. The rock is obviously derived from an ophitic dolerite, but the original augite has been changed to hornblende. The latter mineral has only a slight pleochroism from almost colourless to a pale apple-green. The rock has suffered some crushing as evidenced by lines of granulitized material, and by the occasional fracture of the felspar laths. It is probably to be correlated with the decomposed ophitic dolerite described from Mr. Ferguson's original collection,[1] and is no doubt also a sill in the Lower Division of the Cumberland Bay Series.

2. *Ophitic Dolerite and Basalt.*—These rocks occur in Larsen and Slosarczyk Bays, and also along the coast between Slosarczyk Bay and Cape Disappointment. In hand specimens they are dark, fine-grained rocks, mottled black and white, and with an ophitic texture obvious upon inspection. In thin section the rocks are seen to consist of a plexus of plagioclase laths in ophitic relations with irregular plates of a pale purplish augite. There is also a quantity of green alteration products derived from the pyroxene, and subordinate iron-ores. The felspar gives symmetrical extinction angles in the neighbourhood of 30 degrees, and is therefore an acid labradorite (Ab_1 An_1). Zoning is not conspicuous, and when it occurs there is only a slight change in the composition of the felspar, which becomes andesine (Ab_5 An_3) on the margins of the crystals. The augite forms small anhedral plates of the same order of magnitude as the felspar. Consequently it does not often entirely enclose the felspar laths, but is merely indented by their terminations. It is almost colourless, but frequently becomes a pale brown or purplish-brown towards the edges of the crystals and slightly pleochroic. While the bulk of the mineral is fresh it is changing along the margins to a pleochroic variety of chlorite. Some sections of this substance show a good cleavage, and strong pleochroism from bluish-green to pale yellow. The mineral gives a nearly uniaxial figure, and is probably to be referred to the penninite variety of chlorite. It has suffered much solution and redeposition, and has consequently migrated into the fissures and cavities of the other minerals, especially into the felspars, which are sometimes well reticulated with thin films of chlorite along their cleavage planes. The iron-ore is rather sparse, irregular, and skeletal in form, and is titaniferous, since it gives rise to a grey leucoxenic alteration product. It is usually enclosed in the augite, especially near the margins of the crystals. There is a notable absence of apatite in these rocks.

The quantitative mineral composition of these dolerites is easily obtainable by the Rosiwal method, and is as follows: Plagioclase (Ab_1 An_1), 42·0; augite, 36·7; chlorite, 13·5; iron-ore (titaniferous magnetite), 5·6; pyrite, 2·2 per cent. As is usual with ophitic dolerites the rock is mafelsic (i.e. the felsic constituents are roughly

[1] Tyrrell, op. cit., p. 830.

equal to the mafic), and the felspar and augite are developed in approximately equal quantity.

There is no information as to the field occurrence of these rocks, but their microscopical characters suggest that they probably occur as small intrusive bodies, such as dykes and sills. This impression is strengthened by the presence in the collection of an ophitic basalt which is almost certainly the contact-facies of one of the dolerites. The mineral composition of this rock is identical with that of the dolerites, but it has a much finer grain. There is also a distinct increase in the proportions of augite and leucoxenic iron-ore, whilst the rock is impregnated with pyrite. The augmented proportions of the mafic constituents, and the finer grain, supports the view that this rock is the contact-facies of the dolerite. It is recorded as having been obtained from the coast between Slosarczyk Bay and Cape Disappointment. Doleritic rocks so much decomposed as to merit no further description were collected in Larsen and Slosarczyk Bays.

3. *Alaskite.*—This name was given by Spurr to an Alaskan granitic rock consisting essentially of quartz and alkali-felspars, and practically devoid of ferromagnesian constituents.[1] The rock may also contain a little soda-lime felspar and muscovite. A rock of this type occurs in Cooper Island, off the extreme south-eastern end of South Georgia. In the hand-specimen it is a granular white rock with a very few dark specks representing decomposed biotite. The thin section shows that the rock consists of a granular mixture of quartz and orthoclase. Some of the latter shows mottling between crossed nicols, due to an admixture of the albite molecule, but most of the orthoclase is perfectly uniform and may be regarded as comparatively pure. Occasionally there is a granophyric intergrowth between orthoclase and quartz. The only other constituents are oligoclase in very small amount, and a very few flakes of decomposed biotite.

The quantitative mineral composition of the rock, as estimated by the Rosiwal method, is as follows: Quartz, 31·9; orthoclase, 65·6; oligoclase (Ab_3 An_1), 2·3; biotite, ·2. The rock is therefore practically holofelsic. It corresponds well with the mineral composition (by norm) of the Alaskan types. In three analyses of the latter[2] the quartz ranges from 40·1 to 32·9, the total felspar from 55·9 to 63·8, and ferromagnesian constituents from 1·1 to 2·4 per cent. The South Georgian occurrence is therefore slightly less quartzose than the typical Alaskan rocks.

4. *Quartz-felsites.*—These are compact white, grey, or yellowish rocks in which a minutely nodular or spotted appearance may be frequently seen. These rocks are abundant in Slosarczyk, Larsen, and Drygalski Bays at the south-eastern extremity of South Georgia. They may be divided into two groups according to whether they are spherulitic or not.

Microscopically these rocks consist of small phenocrysts of quartz and felspars in a microcrystalline to cryptocrystalline quartzose

[1] Twentieth Annual Report of United States Geological Survey, pt. vii.
[2] Iddings, *Igneous Rocks*, vol. ii, p. 453, 1913.

groundmass. The latter is often abundantly spherulitic, and has undergone variable amounts of epidotization, a process referred to later. The quartz occurs in small bipyramidal crystals, the angles of which have been rounded by corrosion, and in which corrosion inlets and bays filled with groundmass are common. The euhedral felspars include orthoclase, and a striped variety which has a refractive index well below that of Canada balsam and a maximum extinction angle of 14°. It is therefore a nearly pure albite. Many of the phenocrysts are surrounded by a broad zone of felspathic material which is well marked off from the adjacent groundmass. This is untwinned, extinguished uniformly, and appears to be orthoclase. It occasionally includes a number of minute quartz grains.

The groundmass is entirely crystalline, and consists mainly of minute quartz grains with a minimum admixture of felspathic material. It generally contains numerous spherulites. These are well-formed spherical bodies consisting of radiating bundles of felspathic fibres, with a subordinate amount of quartz. They are frequently built about a nucleus consisting of a crystal of quartz or felspar or, in a few cases, of a graphic intergrowth between quartz and orthoclase. The more perfect growths give a good black cross between crossed nicols. Sometimes, however, the arrangement of the fibres is irregular and the extinction confused. This occurs mostly when there is a series of coalescent bundles or sheaves surrounding the nucleal crystal. With the disappearance of the fibrous habit and spherulitic arrangement this material can be seen to pass into the felspathic zones described above.

All these rocks contain abundant epidote. This mineral occurs mainly in the groundmass and phenocrysts, but rarely invades the spherulites. Consequently, the slides frequently show a striking 'eyed' appearance of circular areas free from epidote, with the latter mineral dominating the concave interspaces. The epidote may also be arranged in long streaks, and is clearly filling up small veins in the rock. In places bundles of fibrous chlorite appear along with the epidote. This process of epidotization is referred to in more detail in the next section, when more extreme products of the process are described.

5. *Lavaform and tuffaceous rocks of doubtful affinities and epidosite.*—In this group is included a series of much-altered rocks, which appear originally to have been lavas and tuffs. The alteration has given rise to epidote, quartz, and chlorite, and its final term is a rock composed entirely of epidote and quartz, and *epidosite*. The least altered rock of the series is a tuff from the coast between Slosarczyk Bay and Cape Disappointment. The angular fragments consist of a greenish or greyish palagonitic material, faintly depolarizing, and containing small phenocrysts of felspar. There are also curious spherical amygdales of a pale-green material with a dark ring near to, and concentric with, their margins. Oligoclase (ext. 6°) is the most abundant felspar, but orthoclase is also present. Little clots of epidote are to be found within each crystal, as elsewhere in the highly decomposed groundmass of the rock, but epidotization has progressed only to a very slight extent in this rock as compared with

those described later. From the association of oligoclase and orthoclase in the phenocrysts this rock may be described tentatively as a trachyandesite tuff.

The next rock, showing a further stage in alteration, is composed of numerous slender microlites of plagioclase felspar embedded in a turbid indeterminate base which doubtless represents original glass. The rock appears to have been an andesite glass. The groundmass now contains abundant chlorite and numerous areas of secondary quartz. Epidote is as yet confined to the large amygdales consisting of an intergrowth of granular epidote and chalcedonic silica.

In the next stage the groundmass is entirely changed to epidote, quartz, and chlorite, but in ordinary light the 'ghosts' of the original felspar microlites are clearly visible. The replacement of the original material has taken place so gradually that the form of the microlites has been preserved. Moreover, the new-formed quartz and epidote is very turbid, as it seems to have replaced the substance of the rock without expelling the turbid dust resulting from previous atmospheric weathering. Only in veins and amygdales is the epidote and quartz free from this turbidity. Small phenocrysts of oligoclase and orthoclase are still clearly visible in one of these rocks, but are in process of replacement by epidote and quartz.

The final stage of the process is a rock composed largely of epidote with subordinate quartz, in which only the faintest trace of the original texture remains. In this rock the new minerals are much clearer than in the one above described, as the turbid impurities, instead of being diffused as before, have aggregated into small clots. In general the epidote is euhedral towards the quartz, and perfectly formed crystals are found completely enveloped in the latter mineral.

Epidotization most frequently represents a reaction between the lime-soda felspars and the ferromagnesian constituents of a rock, doubtless by the agency of percolating solutions aided by some degree of pressure and heat.[1] In rocks containing plagioclase and ferromagnesian minerals the constituents of epidote are there ready-made, and the reaction has excess silica, which crystallizes as quartz for a bye-product. In the rocks above described, especially the quartz-felsites, it is improbable that the constituents of epidote could have been drawn entirely from the elements of the rock. The great amount of epidote in some of the quartz-felsites shows decisively that the mineral could not have been formed from the meagre amount of lime, iron, and alumina available in these rocks. The inference may therefore be drawn that most, if not all, of the epidotic material has been brought in from the outside by percolating solutions. The progressive epidotization described above supports this view, especially if it be taken in conjunction with the facts that the epidote and quartz have occasionally replaced groundmass and felspars without expelling the turbidity resulting from previous weathering, and that in open spaces and vesicles they are quite free from such inclusions. The process has been one of gradual molecular replacement, without

[1] Clarke, *Data of Geochemistry*, 3rd ed., Bull. 616, United States Geological Survey, 1916, pp. 597–8.

disturbing the texture of the replaced rock except in the most extreme instances.

6. *Augitite.*—The pebble of igneous rock in Professor Pirsson's collection is a dark, fresh, vesicular lava, with phenocrysts of a shining black pyroxene. In thin section it shows numerous small phenocrysts of purplish augite and brown 'basaltic' hornblende in a groundmass consisting mainly of augite microlites, with subordinate euhedral magnetite and a colourless glassy base. The augite phenocrysts are usually purplish in colour, but frequently become green towards the interior of the crystals. They are zoned in colour bands, differing slightly in optical properties, and enclose magnetite crystals, especially near their margins. The hornblendes are also euhedral, but are indented by the augites wherever they come into contact. They have a strong pleochroism in shades of brown. The augite microlites of the groundmass are almost colourless, and are embedded in a clear glassy substance of refractive index lower than that of Canada balsam. The rock is entirely felspar-free, and may be regarded as an augitite with hornblende. It is quite fresh and of recent appearance. It is a type of lava which is usually associated with series of alkaline character.

Conclusions.—The study of this collection unfortunately throws very little new light on the moot question of the tectonic relations of South Georgia. The igneous rocks described are probably part of Heim's 'altvulcanischer' area of the south-east end of South Georgia,[1] and belong with the calcic end of the igneous series rather than with the alkalic; but rocks of a distinctively Andean type are still to be discovered. The pebble of augitite found by R. W. Chappell and received through Professor Pirsson is certainly of alkalic type, but on account of its mode of occurrence and isolated character no weight can be attached to it. Hence the question as to whether South Georgia belongs to Suess' "Southern Antilles" and is situated on a great loop connecting the Patagonian Andes with the mountains of Graham Land, or whether it is a remnant of an old sunken continental land, still remains open so far as the petrographic evidence goes.[2] The members of the Weddell Sea party of Sir E. Shackleton's Transantarctic Expedition spent some time on South Georgia on their outward journey, and it is possible that their geologists found opportunity to collect data sufficient to solve this problem.

III.—Pneumatolytic Alteration of a very fine-grained Granitic Rock from Negri Sembilan, Federated Malay States.[3]

By E. S. Willbourn, B.A., Assistant Geologist, F.M.S.

About one mile to the north of the railway station at Ayer Kuning, in the south of Negri Sembilan, one of the Federated Malay States bordering on Johore and Malacca, is a low but conspicuous range of hills covered with long grass. The highest of the

[1] Fr. Heim, *Zeitschr. Ges. Erdkunde*, Berlin, April, 1913.
[2] Tyrrell, Trans. Roy. Soc. Edinburgh, vol. l, pt. iv, p. 832, 1915.
[3] Communicated with the permission of the Government Geologist, F.M.S.

hills, on which is a beacon used by the Trigonometrical Survey, stands about 300 feet above the level of the surrounding country. The general trend of the hill range is in a direction of S. 60° W. to N. 60° E., and there are several hills which branch from the main axis, usually more or less at right angles to it. The eastern half of the range over a distance of about half a mile only need be considered, as there are no rock exposures on the western half.

The framework of the hills is seen to be made up of a white, fine-grained rock, containing small iron-stained cavities, which in its usual weathered state very much resembles a fine sandstone. Examination under the microscope shows it to be a very fine-grained igneous rock, consisting essentially of quartz and mica, sometimes with felspar, and nearly always with abundant blue tourmaline. In one or two places hard fragments of silicified shale were found lying on the hills, and one exposure showed patches of shales included in the white rock. It is doubtful whether these are shales of the Raub Series, which have become non-calcareous through the ordinary processes of weathering, or whether they belong to the younger Gondwana Series, consisting of shales interbedded with quartzites and sandstones. The boundary-line between outcrops of the two series lies in the locality, but its exact position cannot be traced. From the evidence of the dislocation of occasional quartz veins which penetrate the white rock, it is seen to have undergone faulting, and this is confirmed by microscopical examination of the shales. However, the amount of throw of the largest fault observed is only a few inches.

A large outcrop of granite is situated to the south-west, about two miles from the Trigonometrical Survey beacon.

In a hand-specimen the hard unweathered rock is seen to be very fine-grained. It is homogeneous in appearance, except that it contains dark-blue bodies, usually not bigger than a pea, sporadically scattered throughout the rock. They look very much like blots of blue-black ink on white blotting-paper. Under the microscope the rock is seen to consist for the main part of quartz and muscovite. The quartz occurs as irregular grains of a uniform small size, one separated from another by an aggregate of still finer grain, consisting of quartz and muscovite. There are a few flakes of yellowish mica of considerably larger size which contain tiny inclusions. Some specimens of the rock seem to contain no felspar at all. An attempt was made to separate felspar from a crushed sample of the rock by using a solution of mercury potassium iodide of a density such that orthoclase would float and quartz would sink. Some specimens proved to contain no felspar at all, others contained a small quantity of orthoclase.

With still other specimens there is no need at all to use a heavy liquid in order to determine the presence of felspar, for small phenocrysts can be seen under the microscope. These can just be distinguished in the hand-specimen. They are of quartz, orthoclase, and plagioclase with extinction angle corresponding to oligoclase. The rest of the rock is made up of a mosaic of quartz and felspar with occasional flakes of yellowish mica, which contains inclusions.

The quartz grains in the quartz-felspar mosaic are of the same size as those in the quartz-mica rock. The flakes of mica in the former

rock appear to be identical with the few larger flakes of mica in the quartz-mica rock.

The dark-blue bodies mentioned above consist of quartz and blue tourmaline. The quartz occurs as irregular grains of the same size as those in the white quartz-felspar or quartz-mica rock which encloses the bodies.

The tourmaline occasionally shows crystal outline, then occurring as tiny prisms, but usually it occurs as shapeless grains, one of which may enclose two or three of the quartz grains. The dividing line between the quartz tourmaline bodies and the surrounding white rock is very irregular, particularly in the quartz-felspar rock. The tourmaline seems to be replacing muscovite in the quartz-muscovite rock, and felspar in the quartz-felspar rock. The difference in the appearance of the quartz-tourmaline bodies is very striking in hand-specimens of the two rocks, for the bodies in the quartz-muscovite rock appear to have a sharp outline, and their shape is roughly spherical. They weather out in a conspicuous fashion, and in places can be found lying about on the rock surface. The bodies in the quartz-felspar rock have an irregular branching outline.

Sometimes the bodies are more or less regularly distributed throughout the mass of the white rock (quartz-muscovite or quartz-felspar), but in some exposures there is an arrangement along definite parallel planes. One specimen of quartz-mica rock collected from the east end of the hill range shows a large number of the bodies partially amalgamated to form a plate, so that a cross section has the appearance of a string of beads. Under the microscope these bodies are seen to have the same structure as those already described, and the plate, although not unlike a vein, is seen to be very different from certain true quartz-tourmaline veins which were observed in several parts of the hills, penetrating the quartz-muscovite rock. These veins are minute with a thickness of only about $\frac{1}{8}$ to $\frac{1}{16}$ of an inch. They consist of long prisms of blue tourmaline set in a mosaic of clear quartz. The veins are of a very much coarser grain than the parent rock. They have sharply defined walls. Sometimes a prism of tourmaline was observed not to end abruptly at the wall of the vein, but to penetrate for a short distance into the quartz-mica rock. As soon as it left the vein, however, it lost its sharp crystal outline and enclosed the quartz grains of the quartz-mica rock, taking the place of the interstitial flakes of muscovite.

In exposures immediately east and west of the beacon hill, the tourmaline bodies are very small in size, being no bigger than a pin's head. More often than not they are arranged along definite planes, otherwise there is no distinction between them and the larger bodies.

Two small exposures on opposite sides of the beacon hill show a rock of a slightly coarser grain than that already described. Moreover, no tourmaline can be seen in the hand-specimen. Under the microscope it is seen to be porphyritic, the phenocrysts being bleached biotite and quartz with the irregular outline characteristic of the corroded quartz phenocrysts in porphyritic rocks. In addition there are areas of secondary mica whose form suggests that they are altered felspar phenocrysts. The biotite contains needles of rutile associated

with iron-ores and sometimes forming a sagenite web. It is practically uniaxial. The ground-mass consists of quartz and secondary mica. A slide cut from one specimen showed a wavy line, like a crack penetrating the rock, along which occurs some fine-grained opaque material and, at one point, a large grain of blue tourmaline. A specimen of this rock was crushed in order to examine the heavy minerals. Much zircon in small perfect crystals is present and also several grains of blue tourmaline.

This rock resembles an igneous rock which outcrops at the old disused gold-mine of Bukit Chindras, which is situated along the direction of the Ayer Kuning hill range (namely about N. 60° E.), and is between one and two miles distant from it.

The gold-bearing quartz veins strike in a direction approximately north and south. Mr. Scrivenor, the Government Geologist, visited the mine in 1904, shortly after it had been shut down, and he then noted (Preliminary Report on the Gold Mines of F.M.S., Kuala Lumpur, May, 1904) that the country rock is "bleached shale . . . together with a small quantity of a pale green rock which was not seen *in situ*, composed of fine flakes of colourless and pale green muscovite, quartz grains, iron ores, and small prisms of rutile".

The rock can now be seen forming an outcrop on the hillside 70 yards long in a direction about N.W. by S.E. and about 20 yards wide. It is much weathered, but slides cut for microscopic investigation showed phenocrysts of bleached biotite, containing needle-shaped inclusions of rutile associated with iron-ores, with large corroded quartz phenocrysts, and areas of regular form filled with an aggregate of secondary muscovite which may represent felspar phenocrysts. The remainder of the rock consists of an irregular mass of secondary quartz and mica. The rock shows evidence of having undergone strong shearing, and thin quartz veins penetrating the rock have also been subjected to strain. It contains a certain amount of iron pyrites, is plentifully stained with iron, and has numerous cavities.

The rocks described above bear a strong resemblance to the beresites of the Urals described by G. Rose.[1] He describes them as vein rocks which outcrop in talc and chlorite schists, themselves traversed by the gold-bearing quartz veins. Beresite is a very uniformly grained rock, nearly always decomposed and impregnated with iron pyrites. It is made up of orthoclase, plagioclase, quartz, and primary mica, and these are altered to secondary mica and quartz, according to another writer, Arzruni. Some varieties resemble sericite schists, others resemble micaceous sandstones. Original rutile is present as aggregates and as inclusions in quartz. Rosenbusch[2] and also Zirkel[3] quote Helmhacker, who wrote a later description. He says that beresite is a quartz porphyry, poor in quartz, in which the felspars vary in amount, and may disappear altogether on account of their alteration to muscovite and quartz.

[1] Zirkel, *Petrographie*, vol. ii. p. 41, 1894.

[2] H. Rosenbusch, *Mikroskopische Physiographie, II Massige Gesteine*, p. 462, 1896.

[3] Zirkel, *Petrographie*, vol. iii, p. 793, 1894.

As mentioned above, the quartz-muscovite rock of Chindras is traversed by gold-bearing quartz veins, and this is another point of resemblance with beresite. The Malay headman at Ayer Kuning informed the writer that his father had got a small quantity of gold many years ago by washing the soil of the Ayer Kuning hill range, but not sufficient to encourage him to go on with the work.

The elvans of Cornwall resemble these rocks to a certain extent, but differ in that they frequently contain brown primary tourmaline and also they are coarser in grain. Regarding the alteration of elvans, Dr. Flett[1] says: "abundance of fine muscovite in the ground mass of an elvan is probably a certain indication of pneumatolytic action, as muscovite is very rarely a primary ingredient of these rocks." The formation of greisen in the elvans of Cornwall has often been accompanied by the formation of tinstone. The nearest locality to Ayer Kuning in which cassiterite is found in any quantity is at the contact of granite with sandy shales, four or five miles to the west.

The Ayer Kuning and Chindras rocks differ from ordinary greisens in two respects. Greisens are rocks consisting of quartz and white mica, usually with tourmaline and topaz as accessories. The Ayer Kuning rock contains no topaz, and the Chindras rock in addition contains no tourmaline. Also the Ayer Kuning rock differs from other described greisens in its very fine grain. The felspathic portions of it may be described as a very fine-grained granite porphyry.[2]

The Grainsgill greisen[3] is another rock formed probably in a similar way by the alteration of felspar to white mica, and it also is like the Ayer Kuning rocks in that it is deficient in topaz and tinstone, but the latter differ in their very much finer grain.

It seems clear from the specimens examined that all of the Ayer Kuning and Chindras rock was felspathic in the first place, and that in the greater part of it the felspar has subsequently been altered to white mica. This is suggested by the similar texture of the felspathic and non-felspathic rocks, although there is one difference, namely, the lack of phenocrysts in the fine-grained quartz-muscovite rock. However, the coarser quartz-muscovite rock of the beacon hill and of Bukit Chindras contains phenocrysts. The field evidence leaves no doubt that the two rocks are part of the same intrusive mass, for specimens of both the felspathic rock and the quartz-muscovite rock were collected from the same exposure.

There is good reason to believe that the quartz-tourmaline bodies are secondary structures, and not products of consolidation. Their grain is uniformly like that of the surrounding white rock, and the tourmaline, which is always the blue variety, is in the same relation to the quartz as is the secondary mica-quartz aggregate in that it is

[1] Mem. Geol. Survey, Land's End District, p. 65, 1907.

[2] As the ground-mass is not cryptocrystalline but a fine-textured crystalline aggregate of quartz and felspar, the best term is either granite porphyry or microgranite, and granite porphyry is the better of these, because of the phenocrysts.

[3] Q.J.G.S., vol. li, p. 142, 1895.

essentially interstitial. In the quartz-tourmaline veins which are described above the tourmaline is idiomorphic and the quartz is interstitial, but, as has been pointed out before, when one of the long prisms of tourmaline penetrates into the country rock, although the crystalline continuity is preserved, in that the crystal extinguishes as a whole, yet that portion of it in the quartz-mica rock now encloses the quartz grains, so behaving like the tourmaline in the quartz-tourmaline bodies. The arrangement of the bodies along parallel planes could be explained as a flow-structure, but none of the phenocrysts show signs of similar orientation: so it seems to be reasonable to take it as further evidence pointing to the secondary nature of the bodies, and that where this arrangement along parallel planes exists it is due to former planes of weakness in the rock which afforded easy access to mineralizing vapours. The single grain of tourmaline observed in the coarser quartz-muscovite rock exposed on the beacon hill lay in a crack and appeared to have had a secondary origin.

Conclusion.

There is little doubt but that the rock is the result of the greisenization of a very fine-grained granitic rock, some of which has been less altered and can still be recognized as a granite porphyry. The rock, however, was not all porphyritic, and the greater part of it might have been an aplite. Perhaps the alteration of the felspar to tourmaline and the alteration to secondary mica took place in distinct operations. Some specimens of the felspathic rock appear to contain no secondary muscovite at all, yet a considerable quantity of the felspar has been altered to tourmaline. Again, as described above, some of the rock contains practically no tourmaline, and the felspar seems to be completely altered to muscovite. There is an indication that the process of tourmalinization was the later of the two. It has been noted that the quartz-tourmaline bodies in the quartz-felspar rock are much less definite in outline than those in the matrix of quartz and muscovite. The only difference in the two rocks is that one contains much felspar and little muscovite, while the other contains much muscovite and little felspar. Presumably this difference was responsible for the difference in the quartz-tourmaline bodies, and so it must have existed before the tourmalinization occurred.

The origin of the Ayer Kuning rocks and that of the Russian beresites seems to have been very similar. Beresite is a quartz porphyry in which the felspars have been altered to secondary mica and quartz. The Ayer Kuning rock is the result of a similar alteration of a very fine-grained granite porphyry which passes into an aplite without phenocrysts. The Chindras rock contains little or no tourmaline, but in Ayer Kuning rocks the blue tourmaline is a characteristic feature. A point of difference between these rocks and beresite is that the latter is rather poor in quartz owing to the small amount in the original quartz porphyry. The Ayer Kuning granite porphyry appears to have been of normal composition.

IV.—The Ophiolithic Groups of the Ligurian Apennines.
I. Western Liguria.

By C. S. Du Riche Preller, M.A., Ph.D., M.I.E.E., F.G.S., F.R.S.E.

THE groups of ophiolithic, that is, crystalline ferro-magnesian rocks in the comprehensive sense, to be dealt with in this and the subsequent paper are those west and east of Genoa.[1] Of these the principal western or Voltri group was already referred to in the preceding paper[2] as being, on its western margin, contiguous to the crystalline massif of Savona, and as constituting with the latter the geological contact-zone of the Alps and the Apennines. The anomaly of its position and petrological character is enhanced by the abrupt, clean-cut division of its eastern margin from the adjacent, more recent, and smaller ophiolithic group of Sestri and Isoverde, which is coeval with the groups of Eastern Liguria.

The Groups of Western Liguria. (Fig. 1.)

The border of the large and important area known as the Voltri group runs on the south, from its contact with the Savona massif near Varazze, along the Riviera to Cogoleto, Arenzano, Voltri, Prà, Pegli, and Sestri Ponente; then north up the Chiaravagna Valley, to Isoverde in the Iso Valley, to the Bocchetta Pass on the crest of the Apennines, and thence to Voltaggio in the Lemmo Valley. From here it extends, as the northern margin, across the Corrente, Stura, Orba, and Erro Valleys to near Ponzone, south of Acqui, whence it turns south to the Giovo Pass and Corona, and along the contact line of the Savona massif down to the coast at Varazze. The divide of the Apennines runs more or less parallel to the coast from the Giovo Pass (522 m.), to Mte. Ermetta (1,262 m.), Mte. Reisa (1,184 m.), the Turchino Pass (552 m.), Mte. Penello (996 m.), and the Bocchetta Pass (777 m.), so that only the southern part or about one-third of the area lies in Liguria proper, while the northern and larger part belongs to the Po watershed; in its entirety the complex, covering no less than 36 by 22 km. or 800 square kilometres, is by far the largest in the Apennines. It exceeds even that of the Lanzo Valleys in the Piémontese Alps; like the latter it has, owing to its prevalently peridotitic and serpentinous rocks, resisted denudation and hence preserved its compactness, continuity, and also its often austere aspect in a remarkable degree. The three principal roads along which, besides the coast-road, the ophiolithic and sedimentary rocks of the area may be studied, are those crossing the Apennines south to north from Varazze by the Giovo Pass to Sassello and Acqui on the west, from Genoa by the Bocchetta Pass to Voltaggio on the east, and from Voltri by the Turchino Pass to Campoligure, Rossiglione, and Ovada in the centre, to which last-named runs in great part parallel the railway from Genoa to Ovada.

[1] The term ophiolithic, though in its original and narrow sense it refers only to serpentines, applies to eruptive basic rocks or pietre verdi comprehensively, irrespective of age, like, e.g., the 'roches ofitiques' of the Pyrenees.

[2] Geol. Mag., September, 1916, p. 400 et seq.

Fig. 1. Sketch Map of Voltri Group, Western Liguria.

Fig. 2. Contact of Trias and Eocene, Monte Gazo, Chiaravagna Valley.

The Voltri group is composed almost entirely of Mesozoic, dark-grey, often talcose calc-schists, and infolded, intercalated, and overlying pietre verdi. As such it belongs geologically to the Alps rather than to the Apennines, and the anomaly of its position consists in its being wedged between the Savona crystalline massif at one end and the Eocene formation at the other. Up to 1882 it was variously assigned to the Archæan, Palæozoic, and, more often, to the Tertiary formations, and it was not till Issel and Mazzuoli's investigations of 1883 and 1884 [1] that a clean-cut line of division was shown to exist north of Sestri in the Chiaravagna Valley, and thence to Isoverde between the older Triassic Voltri group on the western and the more recent Eocene ophiolithic and sedimentary series on the eastern side of that line.

The determining factor in this division was Issel and Mazzuoli's discovery of several isolated deposits of Triassic dolomitic limestone immediately west of the line between Sestri and Isoverde, viz. on Mte. Gazo, Mte. Torbi, and Mte. S. Carlo, and also north of the crest of the Apennines near Voltaggio, while more recently Rovereto [2] elucidated those of Cogoleto and Arenzano on the coast, and Franchi [3] also adduced valuable evidence of the Mesozoic age of the Voltri group. These dark-grey and bluish, cavernous, sparsely fossiliferous (gyroporelle) limestones are, like their equivalents in the Maritime Alps and the Savona region, as also like the grezzoni of the Apuan Alps,[4] indubitably Middle Triassic, underlying normally the Upper Triassic calc-schist and pietre verdi horizon. The three deposits between Sestri and Isoverde present the abnormal phenomenon that they rest on serpentine and amphibolite of that horizon instead of vice versa.[5] This reversed sequence is, however, purely local and is due to an inverted fold along the greatly disturbed, faulted, and tilted contact of the Triassic and Eocene formations, whose marked unconformity is e.g. well exposed in the Chiaravagna Valley on the eastern flank of Mte. Gazo, as also in the Rio Recreusi ravine on the eastern flank of Mte. S. Carlo near Isoverde. Along the coast near

[1] L. Mazzuoli & A. Issel, "Sovraposizione nella Riviera di Ponente d'una zona ofiolitica eocenica ad una zona ofiolitica paleozoica": Boll. Soc. ital., 1883, p. 44 et seq. "Zona di coincidenza delle formazioni ofiolitiche eoceniche e triassiche nella Liguria occidentale": Boll. R. Com. geol., 1884, p. 2 et seq.

[2] G. Rovereto, "Questioni dei calceschisti studiata in Liguria": Boll. Soc. geol. ital., 1909, p. 408 et seq. "Schisti e serpentine antichi in Liguria": Atti Soc. Ligure Sc. nat., vol. ii, 4, 1891.

[3] S. Franchi, "Massiccio cristallino ligure": Boll. R. Com. geol., 1893, p. 43 et seq. "Relazione campagna, 1911": ibid., 1912, p. 41. "Posizione della zona a *Helminthoidea labyrinthica* nell'Eocene superiore": ibid., 1915, p. 297. Franchi claimed the Voltri group as belonging to the Mesozoic calc-schist and pietre verdi horizon of the Maritime and Cottian Alps in "Zona Pietre Verdi, Ellero e Bormida", ibid., 1906, p. 89 et seq.

[4] Both the Ligurian and the Apuan dolomitic limestone, independently analysed, contains 58 per cent carbonate of lime and 38 per cent carbonate of magnesia.

[5] This superposition Mazzuoli and Issel regarded at the time as normal. They therefore assigned the calc-schists and pietre verdi to the Lower Trias, and figured these as such in their map of Liguria of 1887. The formation is now, like that of the Piémontese Alps, recognized as Upper Triassic.

Cogoleto and Arenzano the sequence is normal, the dolomitic limestone and quartzite here being, moreover, as Rovereto has shown, underlain by Lower Triassic quartzite and conglomerate and Permian schist as the substratum. Another curious phenomenon is the wedge of calc-schist, quartzite, and mica-schist which projects from the belt of these rocks on the coast into the pietre verdi area north of Voltri for about 12 kilometres to Mele, the Turchino Pass, and beyond to Masone and Campoligure. This wedge, very similar to the Santuario island in the Savona region, is up to 4 kilometres wide, and divides the Voltri group on the Ligurian side into two unequal parts. Except an outcrop of serpentine in the Stura Valley immediately north of the road-tunnel on the Turchino Pass, it is practically denuded of pietre verdi.

The Eocene formation east of the contact line and thence to the Polcevera Valley, north of Genoa, is composed as usual of fossiliferous (*Helminthoidea*) limestone, argillaceous, often shaly schist, and macigno sandstone. It is in the argillaceous schist between Cornigliano and Sestri, viz. between the Polcevera and Chiaravagna Valleys, that occurs the mass of ophiolithic rocks which extends from the headland of S. Andrea north to Borzoli and Madonna della Guardia for about 8 and 2 kilometres in length and width, while further north several smaller masses crop out at S. Martino, near the Bocchetta Pass, and between the latter and Voltaggio, forming a fringe round the eastern margin of the Voltri group. As in the Savona region, so also in the Voltri area deposits of Oligocene conglomerate and breccia are frequent and extensive, one of the largest being a bank 500 metres in thickness in the Morsone Valley near Voltaggio, which is entirely composed of pietre verdi débris.

The relation of the Voltri group to the adjacent one of Sestri and Isoverde has been the subject of considerable controversy. De Stefani[1] and Termier & Boussac[2] regard the Voltri group as an integral part, not of the Alps, but of the Apennines. In Termier and Boussac's view there is between the two sedimentary and ophiolithic formations no division or discontinuity, but a gradual passage from Triassic to Post-Triassic, the former being simply more metamorphosed than the latter, and both constituting a consecutive series after the pattern of the French Alpine *séries compréhensives*. Sacco assigns the argillaceous schists and the macigno sandstone, including the ophiolithic rocks of the Sestri and Isoverde group, to the Cretaceous, and the uppermost fossiliferous (*Helminthoidea*) limestone strata to the Lower Eocene.[3] The weight of evidence is, however, largely in favour of a distinct difference and division between the two unconformably juxtaposed sedimentary and ophiolithic formations, the Voltri group being Triassic and that of Sestri and Isoverde prevalently

[1] C. De Stefani, "La zona serpentinosa della Liguria occidentale": Rendiconti Atti R. Acc. Lincei, Roma, 1913, pp. 547 and 661 et seq.

[2] P. Termier & J. Boussac, "Passage latéral N.O. de Gênes de la série cristallophyllienne (schistes lustrés) à la série sédimentaire-ophiolitique de l'Appennin": Comptes Rendus Acc. Sciences, Paris, 1911, p. 1361 et seq.

[3] F. Sacco, "L'Age des formations ophiolitiques récentes": Bull. Soc. belge de Géol., vol. v, 1891. *Carta geologica Appennino centrale 1 : 100,000*, Torino, 1891.

Upper and Middle Eocene. The division is shown e.g. in the interesting superficial section of Mte. Gazo in the Chiaravagna Valley (Fig. 2).[1]

The principal constituents of the pietre verdi of the Voltri group are peridotite, lherzolite, serpentine, and euphoditic, amphibolic, eclogitic, and garnetiferous rocks. Although in some cases well preserved, they exhibit more generally various stages of alteration, schistosity, and decomposition, and are, moreover, so interfolded and intermixed both with each other and with the enclosing, often talcose calc-schists that their delimination and subdivision is as difficult as in the similar case of the Lanzo Valleys. The peridotitic and serpentinous rocks alone are easily distinguished by the dark colour, the rugged outlines, and the barrenness of their outcrops, in contrast to the other pietre verdi and the calc-schists often covered with abundant vegetation.

Along the coast-road between Pegli and Prà the headlands exhibit outcrops of dark, dull serpentine and euphodite with glaucophane, in part brecciated and decomposed, alternating with shaly, talcose calc-schist which fringes the coast from Sestri to Voltri.[2] North of Pegli in the Varenna and upper Gorzente Valleys appear lherzolite and serpentine with euphodite veins, and north of Prà, as also north of Voltri, in the Acquasanta ravine, occur considerable rugged outcrops of dark-green and black peridotitic rock, which from their forbidding appearance are known as the Scogli Neri and the Scoglio del Diavolo. Beyond Voltri a large mass of serpentine continues to Arenzano and Cogoleto, where it alternates with peridotitic rock and calc-schist. Between Cogoleto and Varazze a large mass of euphodite stretches north, while at Varazze the dark-green serpentine shows euphodite veins. Thus, the continuous mass of peridotitic and serpentinous rocks, with associated euphodite and alternating with calc-schist along the littoral, is interrupted only by the calc-schist wedge of Voltri and Campoligure previously mentioned.

Along the eastern margin similar outcrops of enstatitic and diopsitic lherzolite, glaucophanic euphodite, and amphibolite appear on the western flank of Mte. Gazo, while further north serpentine predominates west of Mte. Torbi; again, west of Mte. S. Carlo in the Iso Valley a lherzolitic mass exhibits euphodite veins, and lherzolite and serpentine also crop out in Mte. Persucco and Mte. Roncasci, west of Caffarella. From here extends on both sides of the Apennine crest the great euphodite mass of Mte. Lecco, probably connected with the similar mass north of Varazze in the south-western part of the area. In this, as in the other euphodite masses, the rock varies from the well-preserved diallagic to the altered type with saussurite and smaragdite, and is often gneissiform, laminated, and schistose. In the Olba Valley, north of the Apennine crest, occur considerable eclogitic masses, and along the western margin contiguous to the

[1] This section is deduced from Rovereto's more extensive one, op. cit., p. 414.

[2] Professor Bonney described some of the coastal rocks between Sestri and Prà in "Notes on some Ligurian and Tuscan Serpentines": GEOL. MAG., May, 1879, p. 362 et seq.

crystalline massif of Savona, the pietri verdi, which overlie the latter at Corona, present the usual varieties already mentioned.

Although the Triassic pietre verdi of the Voltri group and the Eocene ophiolithic series are both of eruptive origin, they exhibit certain differences, not of substance, but of facies and degree. Thus, the older serpentines are more uniformly dark and dull in colour, the younger generally a brighter, richer, and more lustrous green, with varicoloured passages; again, the pietre verdi when schistose often pass to the infolding calc-schists, whilst the Eocene rocks are more clearly defined from the sedimentary strata. The former are more often amphibolic, the latter more pyroxenic, viz. diabasic. The serpentino-calcareous rock 'ophicalce' is rare in the Voltri group, but not infrequent in the Eocene series, and the same difference applies in an enhanced degree to metalliferous deposits. These differences are clearly exhibited in the Eocene ophiolithic series of Eastern Liguria, as well as in the smaller, essentially serpentinous and diabasic masses infolded in the Eocene sedimentary strata between Sestri and Isoverde and bordering on the eastern margin of the Voltri group. Among these are notably the outcrops of the S. Andrea headland on the coast near Sestri; of S. Rocco, east of Panigara in the Chiaravagna Valley; of Borzoli and of Madonna della Guardia at the northern end of that mass;[1] again, further north, those of Caffarella and S. Martino, which latter village is built on Eocene serpentine; and lastly, the Eocene serpentine with calcite veins known as "verde di Polcevera" of Pietra Lavarezza, just below the Bocchetta Pass, which vies with the similar rock of Levanto in Eastern Liguria.[2] Beyond the Pass Eocene serpentine and diabasic rocks appear in the Lemmo Valley near Molino di Voltaggio along the Bocchetta road and in the lower part of the Acquastriata ravine, whose upper part lies, however, in calc-schist and pietre verdi. Some further small masses near Voltaggio complete the Eocene fringe.

As regards the anomalous position of the Voltri group east of the Savona massif, there is an obvious correlation between it and the underlying dolomitic limestone, the isolated outcrops of which all round the group can only be remnants of a much more extensive and continuous formation which reached west to the Savona massif and the Maritime Alps. That formation must have been overlain by a similarly extensive one of calc-schists and pietre verdi; hence, in the intervening gap in the Savona region the two formations must either have been removed by erosion and denudation or they must have been pushed over from the Maritime Alps. The gap in the

[1] Near Borzoli occurs the amygdaloidal calcareous diabase called borzolite, and west of Murta the cavernous variety called coschinolite by Issel. Madonna della Guardia is almost entirely built on diabase.

[2] The serpentine of Pietra Lavarezza with associated ophicalce is overlain by diabase which forms the left bank of the upper Riasse torrent. In the Recreusi glen, where the unconformable contact of the Triassic limestone and the overlying Eocene argillaceous schist is conspicuously exposed, occur, along the junction of the Eocene ophiolithic rocks, large masses of Triassic gypsum which are quarried near Isoverde.

Savona region between the calc-schists and pietre verdi in the north-eastern part and those of the Bormida Valleys on the western margin is only about 15 kilometres; it may, therefore, be legitimately assumed that the gap was simply eroded, that both the Triassic formations—dolomitic limestones and calc-schists with pietre verdi—originally extended from the Maritime Alps continuously to the Voltri group, and that the latter, of submarine sedimentary and eruptive origin, was formed *in situ* rather than by an overthrust from the west. In either case it is, by reason of its Mesozoic age, geologically Alpine in character, and constitutes, together with the Savona crystalline massif, the contact-zone of the Alps and the Apennines.

V.—Mining in the Federated Malay States.

[In the Geological Magazine for June last, p. 255, Mr. W. R. Jones refers to a *Preliminary Report of Mining in the Main Granite Range, Federated Malay States, 1913*. This report bore a slightly different title, and was *not published*. It is the property of the Federated Malay States Government, but I have the permission of the Chief Secretary to forward to you a typescript marked "Office Copy" and initialled by Mr. Jones, and to ask you to publish that portion of the report which refers to Gunong Bakau.—J. B. Scrivenor, Geologist to the F.M.S. Government.

Geologist's Office, Batu Gajah, *July 14, 1916*.]

Preliminary Report on Tin-mining on the Main Range at Ulu Bakau and neighbourhood.

Hemy's Lode, Ulu Bakau (*Sungei Bakau Mine*).—At a height of about 4,500 feet tin-ore is found in this mine in undecomposed granite which has to be crushed by foot-stamps before the cassiterite can be recovered. The rock is a medium-grained granite, very rich in quartz, muscovite, and cassiterite, and relatively poor in felspar. Microscopic sections show that the greenish colour, so noticeable when the rock is wet, is due to the presence of chlorite formed by the alteration of the muscovite and pale-coloured biotite of the original granite. The rock here is very different in appearance from that in Mr. Bibby's mine, but agrees with it in the low percentage of felspar.

An interesting point in a granite so heavily mineralized is the small amount of pyrite and mispickel on the one hand, and the abundance of tourmaline on the other. I have noticed this in other cases, and although the two classes of minerals do occur together in the same mine, yet the abundance of one class seems to be at the expense of the other class. This is well illustrated in Mr. Bibby's mine, where one part is very rich in tourmaline and topaz, whereas the other (the one near the aerial rope-way) is extremely rich in mispickel and pyrite. The explanation is that where tourmaline and topaz are abundant, the tin-ore came up originally as the vapours of fluorine and boron; and where mispickel and pyrite are predominant the vapours of sulphur and arsenic were the mineralizers. So persistent is tourmaline in Mr. Hemy's mine that the Chinese call it by a name which means "the friend of tin", and I have no doubt if they could

distinguish topaz from quartz they would know the former mineral also by a name signifying intimate relationship with cassiterite.

The rock is phenomenally rich in tin-ore, and typical specimens were collected and found to contain 23·9 per cent of cassiterite. The extraordinary enrichment occurs at the intersection of two main lodes and one subsidiary lode.

The mine is worked on 55 per cent tribute, with the result that only the very rich 'lode-stuff' is crushed, and attention is given, not to the ultimate economic development of the mine, but to the recovery of as much tin-ore as possible before a certain date.

Granite containing from five to six times the percentage of ore profitably worked in Cornwall is at present being thrown on the dump-heap, but under the circumstances this is justifiable, and as the dump-heap will eventually be worked there is no ultimate waste of the country's mineral resources. Water is very scarce, and the rock, after being crushed by foot-stamps, accumulates more rapidly than it can be treated. A heavy shower of rain enables the accumulation to be washed, and so the work goes on.

"*Bibby's Lode.*"—This mine is also situated at Ulu Bakau, but is on the Pahang side of the main watershed. The tin-ore is obtained from the undecomposed rock, and it is interesting to note that there are distinct differences in its character in different parts of the mine. These differences illustrate in a striking and conclusive manner the well-known theory of "Differentiation of Granite", and it will be helpful for the economic development of the mine to bear in mind that the differences in the rock are more apparent than real; that what seems to be a totally different kind of rock is only a modified form of its neighbour. The whole of Ulu Bakau and the neighbourhood is formed of granite and its modifications, viz. pegmatites, aplites, quartz veins, and topazized granite or greisen. The latter rock is extremely interesting as evidence of great mineralization, for the accepted theory of its origin is that it is formed by the action of fluoriferous vapours on the felspar of the granite. The presence of such a fluoride mineral is an indication, not only of mineralization, but also of tin-ore, which originally came up as the vapour of tin-fluoride. In this particular instance the topazized granite itself contains cassiterite. Good washes were obtained from such a rock on a mining lease about a mile along the path from Ulu Bakau. So far no work has been done on this spot.

Some of the mining engineers who have prospected this property have to some extent agreed that the hill has one wide horizontal lode running through it and six smaller lodes, also parallel, which run through part of the hill. The views they have gathered after careful work extending over some months are worthy of serious consideration, but the following observations will, I believe, offer another solution to an extremely interesting problem.

1. A main horizontal lode with other smaller parallel lodes running through a considerable hill would be a remarkable occurrence anywhere; and in a district where faulting and thrusting have occurred on a tremendous scale it would be an extraordinary although not impossible disposition of the lodes, but in a hill which itself shows distinct faulting and thrusting it would be impossible.

2. The bands of tin-ore-bearing rock cannot be taken as evidence of parallel lodes, for (1) the intervening rock has not been prospected except in a few places on the surface; (2) the actual outcrop of bands of rocks of the same strike would all appear as parallel *outcrops* on a hillside, no matter how great the variation in dip may be.

3. It is proved that the dip of this main lode varies from 15° in one direction to 5° in the opposite direction. The simplest explanation of such a variation in a faulted igneous rock is a fault, and such faulting is clearly shown in photographs.

4. What is supposed to be the most convincing argument in favour of the horizontal lode theory is the horizontal upper surface of the tin-bearing ground shown in photographs.[1]

It will be noticed, however, that the character of the rock shown above this horizontal surface is totally different from the underlying rock, and not only is it a much less acid type of granite but it is decomposed and contains granite boulders. The junction of the unweathered and weathered granite is remarkably sharp and well defined, and further evidence is at hand in the adjacent cutting in the same hill, on the same level, and within a hundred yards of the previous exposure.

The faulting and thrusting caused a landslip which brought down the soil from higher up the mountain, smoothed the surface of the rock, and gave it the polished surface which it still possesses. Such landslips are common even to this day, and two fresh examples on Gunong Raja can be seen from Ulu Bakau.

This explanation also accounts for the disturbed and broken character of the rock between the fault and thrust planes and, what is quite interesting, accounts for the formation of the steep valley immediately below where the rock, broken and crushed by the movement, was easily transported by water, leaving the more compact rock to form the steep sides of the valley. Such a case also occurs at Gunong Raja, where one side of the valley is a huge polished perpendicular wall.

5. Numerous other pieces of evidence against the horizontal lode theory could be pointed out on the ground, but perhaps sufficient evidence has been given to show that it would be utterly unsafe to attempt a calculation of the amount of tin-bearing rock in this hill with the facts now available.

The question can, however, be approached in another and safer way, and one which will furnish the Government with a better conception of the amount of tin-bearing rock in this part of Ulu Bakau.

Very strong mineralization is to be seen on Messrs. Bibby & Ruxton's property over an extensive area, but in parts the rock is barren of tin-ore. The barren areas are considerable, and the amount of non-payable cassiterite-bearing rock is also extensive. There is on this property, however, sufficient *proved* ground to give the mine a life for many years, and there is every indication of mineralization extending right into the mountain and into the adjoining land on

[1] The junction is between a quartz-topaz vein and porphyritic granite.—J. B. S.

the Selangor side of the watershed, the one leased by Towkay T. Kim Bee.

The few adits driven into the mountain-side on the Selangor boundary show the presence of the tin-ore-bearing rock now being profitably exploited on the Pahang side, namely, a fine-grained to saccharoidal topazized granite or greisen passing into a quartz rock containing only a little topaz, and in some places into quartz free from topaz. The cassiterite is disseminated through the rock. The picked material crushed by foot-stamps was found to contain 6·8 per cent of tin-ore, and in another place 4·2 per cent, whereas the rock crushed at the mill varied from 1 to 2 per cent. These figures were obtained from specimens collected on my visit, but considerable variation occurs daily, although the average from the whole mine may be fairly constant.

The mineralization in this neighbourhood is so general and extensive that it is safe to predict for tin-mining a life of several years, if, of course, the metal remains at a good price.

About 60 chains to the south-east of the Trigonometrical beacon of Ulu Bakau is a mine now being worked by lampanning. A vein of cassiterite-bearing rock has been exposed for a distance of 61 feet, having a direction of 31° south of east. The Chinese knew that this contained tin-ore and were enthusiastic over it, but confined their attention to lampanning for the present. There is considerable amount of lampanning to be done, but the tailings will not, fortunately, cover up the exposed veins.—W. R. J.

GEOLOGIST'S OFFICE, BATU GAJAH, F.M.S.
September 23, 1913.

VI.—THE UPPER TRIAS OF LEICESTERSHIRE.

(*Continued from the September Number, p. 422.*)

By A. R. HORWOOD, F.L.S.

8. ECONOMICS AND WATER SUPPLY.

THE economic resources of the Trias as a whole are not great, if we exclude the two main industries (bricks and gypsum), but they are of interest from a practical standpoint, so that a short summary will be given here.

The great impetus given to the quarrying of granite, syenite, and allied igneous rocks by improvements in blasting and boring methods has more or less caused the industry in Triassic building stones to become obsolete.

At one time thick-bedded sandstones were used for building stone at Kegworth and other places in that district, and they were formerly worked at Burton, Bretby, Castle Donington, Donington Park, Weston near Ashby, and at Warton, just outside this area; but they are rather soft, though hardening on exposure, and sometimes cemented by barium sulphate. They are worked at Melbourne and Weston.

In the Upper Keuper[1] the Dane Hill Sandstone series has been

[1] Locally some thick-bedded skerries have been utilized in some cases.

worked at Dane Hill, where old quarries still exist. Many of the Roman architectural remains in the Leicester Museum testify to its use in Roman buildings. It hardens on exposure, but is friable and soft. The Orton-on-the-Hill Sandstone group[1] has been used for building at Diseworth and Kegworth, and probably at Orton, but no quarries now exist.

Building sand is obtained from the Lower Keuper near Atherstone, and it is used for the same purpose at Leicester, the Upper Keuper Dane Hill Sandstone being utilized. Where of a sandy character the Upper Keuper marls are used for sand at Leicester. The marls of the Lower Keuper are used for brick-making at Coalville, Ellistown, Ibstock, Heather, Measham, and about Atherstone, as well as in the Nottingham and Derby district.

In the Red Marl area brick-making is carried on extensively, being the main industry, close to the principal towns and lines of railway. Some forms, with much lime and skerry, are unsuitable for this, but the higher beds as a rule yield a good form of brick-clay, and the local glacial clays when free from stones are sometimes mixed with them, as at Sileby and near Leicester. Pits are at work at Hathern, Loughborough, Sileby, Belgrave, Thurmaston, Knighton, Blaby, Glenfield, Bagworth, Ashby, Waterloo Hill, Burton, Quorn, Hoton, Walton, and elsewhere.

The Tea-green Marls have been utilized for brick-making at Glen Parva and Gipsy Lane, and formerly at Spinney Hills, and in the Rhætic beds of that place and at Glen Parva, but the last-named pit is now filled with water.

Road-metal was obtained from the Orton Hill Sandstone at Diseworth, and the flinty limestones of the Upper Rhætics have been used in South Notts. The Rhætic limestones and nodular limestones of the Tea-green Marls figure as tesseræ in the local Roman pavements.

Gypsum locally is not of such importance as at Newark and elsewhere in Notts. In this area it is worked at Gotham, Thrumpton, Kingston, and West Leake, where it is ground for plaster. Near Leicester the only use to which it is put is for grotto work, and it can be obtained for 5*s*. a cartload. Some ornamental work was formerly executed in the district, however, as the alabaster font at Old Humberstone Church was made from the Gipsy Lane mineral. Plaster is only made to a limited extent at Leicester. It was formerly mined at an old pit on the Regent Road. To a slight extent it is used as a top dressing for soils,[2] but since the introduction of artificial manures the practice has been largely discontinued. The fibrous gypsum or satin spar from which ornaments are made is of as good quality and sometimes nearly as thick as in Notts, where it sold for £6 to £7 a ton at one time and was sent to Derby, where it was made into brooches, bracelets, etc., and shipped abroad. Formerly the alabaster industry must have been carried on locally, as many ecclesiastical monuments

[1] The stone was used for threshing-floors at Orton, Austrey, Copt Oak, Charley, where bricks were also made.

[2] Fetching at one time 10*s*. a ton.

and ornaments exist in the churches of Leicestershire, and it is improbable that they all came from Tutbury, where it was largely worked years ago, and where mural tablets, etc., were made. In Tutbury Church are tombs dedicated to Henry de Ferrers and Sir John de Hanbury, and ornament of Norman age adorns the pillars, whilst alabaster tombs at Norbury, Ashbourne, Newton Sulney, Burton (knight temp. Edward III), and elsewhere were made from the Tutbury rock. During the fourteenth century up to the Commonwealth period alabaster was an important industry at Burton.

Chellaston now takes the place of Tutbury and Fauld. At the former the gypsum is 14 feet thick, and is sent to Derby, Buxton, and the Potteries, a large amount of plaster of Paris being used in modelling and as an imitation marble in Scagliola. It is used for obtaining copies of sculptures, medals, gems, and a variety of other things of which a replica is required, figuring largely in museums, for moulds, for electro work, stereotyping, glasswork, cornices, plastered ceilings, panels, pilasters, etc. The large tazza at the Museum of Practical Geology came from Fauld, where slabs 9–10 feet are manipulated.

Another use for gypsum is for Burtonizing beer. In the Burton beers some 350,000 lb. of gypsum are annually consumed. A similar water is utilized for brewing at Newark, the proportion of sulphuric acid being over 65 per cent, in the Burton waters 57 per cent. The Leicester breweries are supplied with water which also contains much sulphate of lime diluted down to 40 grains per gallon from 100.

The soils of the Lower Keuper are loamy and retentive, but friable and suitable for arable, that is, the marls, which give a red loam, which is equally adapted to arable, grass, or orchards, and market gardens, as seen in the Mease Valley.

The Upper Keuper Marls form good cornland, but require subsoil drainage. The percentage of silica is over 50, alumina 15, lime 3–4, magnesia 5, potash 4, and carbonic acid 4 per cent. Where the subsoil is sandy a loamy soil results. This is modified by the occurrence of skerries and mixture with drift, often, as around Melton, pebbly. It forms good pasture, being stiff and clayey, and like most red beds is excellent for fruit-trees. Trees grow well upon the sandstone horizons.

The Tea-green Marls form only a narrow band and are less siliceous and more calcareous than the Red Marls in this respect, approaching the Rhætic beds, which contain more carbonic acid (20 per cent) and more lime.

The Bone-bed, which in some districts contain phosphatic nodules, yielding manure, is here only a gritty or pebbly sandstone. There is no trace of a bone-bed in the Tea-green Marl, such as that at Gold Cliff, but palæontologically it is represented by a series of definite bands with fish-scales. Some of the marly limestones are practically similar to Fuller's Earth, and a clay at the base of the Tea-green Marl has been worked at Emborrow, Somerset.

Economically the Red Marl has been classed with Chalk Marl, Fuller's Earth, Kimeridge Clay, Gault Clay, and London Clay, all

highly fertile formations, and the red beds have been characterized as the most fertile land in England. The red colour which is indicated by the name Ratcliffe, Red Hill, is retentive to the rays of the sun in marked contrast to the blue clays of the Lias, which are not suited to arable land as a rule, thus differing from the Marlstone, which yields also a red and fertile soil (cf. Rutland).

Thus, in so far as Leicestershire is concerned, the Upper Trias constitutes the richest part of the county, apart from the mineral products, the Middle Lias (if we exclude the syenite and Barrow limestone and coal industry) coming next in respect of the soil fertility and mineral resources. There is so little Oolite in the county that its much higher relative soil value need not be taken into account.

The main source of water supply from the Upper Trias is the Lower Keuper Sandstone, called Waterstones. This name, however, is unfortunate, for it really applies to the character that the marls possess in regard to texture, resembling the appearance of watered silk,[1] which is well shown in the sections at Appleby. At the present time the supply of water from the Trias is not generally utilized, the larger towns, such as Loughborough and Leicester, receiving their water from Charnian reservoirs or from the upper reaches of the Derwent, largely derived from Millstone Grit and older Palæozoic rocks. Formerly many small villages received their supply from the Lower Keuper, and the distribution of villages along the outcrop indicates the importance of this formation at one time as a water-bearing stratum. Its abundance at certain horizons is shown by the following borings. At Newtown Unthank water overflowed the top of the borehole, sunk to a depth of 615 feet, the Waterstones being 120 feet thick, Coal-measures 353 feet, water being met with first at a depth of 220 feet.

At Hathern a boring was made to a depth of 320 feet below 140 feet of Lower Keuper Sandstones into conglomerates, and water was abundant. At Chilwell water rose to the top of the boring, 435 ft. 9 in., from below Waterstones 115 feet, with Bunter and Permian beds beneath.

At the Spinney Hill boring water was met with in a boring of 600 feet (increased later) at 400 feet in Waterstones (232 feet), or more probably Red Marl. At Lindridge water overflowed the top of the borehole (270 feet) when Waterstones were reached. At Elmesthorpe it was found to be constant at 800 feet in a boring 1,440 feet, the Waterstones being 330 feet and the Coal-measures 980 feet thick In a boring at Hinckley, one mile W.N.W., made November, 1877, the water rose to 237 feet from the surface in a boring 805 feet deep from Waterstones. There were 530 grains of solids and 39 grains of chlorine in the imperial gallon, and the yield was 400,000 gallons per day. The same feature was noticed

[1] The marls are impervious and dry, the sandstones pervious, 60,000 gallons per hour being obtained from waterstones at Ellistown at a depth of 300 feet, and at a depth of 670 feet in another boring pure limpid water rose 40 feet above the borehole.

in borings at South Scarle, where water rose from 1,500 feet to 5 feet above the top of the borehole, and at Retford, where it rose to within 6 feet of the surface from a depth of 600 feet. At Ibstock at a depth of 108 feet the supply of water was 6, 8, and 9 gallons a minute, at Bagworth from conglomerate 600 gallons per hour at a depth of 299 ft. 4 in. At Snarestone 80 gallons per minute were registered at 51 feet, 100 gallons per minute at 99 feet (from a marl parting below pebbles), and 200 gallons per minute at 109 ft. 3 in. The water is thus abundant and permanent. It is not so hard as that from the Upper Keuper Red Marl (always scarce) and sandstones. The water percolates along the outcrop along the line of dip, and is prevented from escaping by the intercalated marls, so that artesian wells are suitable for securing a supply from it.

Little water is derived from the Red Marl, and such as it is is too hard for potable purposes, though, as has been mentioned, it is excellent for Burtonizing beer. Where sandstone bands or skerries are intercalated with it and gypsum beds, however, a certain supply is obtainable. Some of these sandstones outcropping on hillsides take up water in the same way as the Lower Keuper, and it flows down the dip, but the supply is limited, as is also the supply from the gypsum bands.

At Burton an analysis of water obtained from an artesian well at a depth of 70 feet, used for brewing, was as follows:—

	Grains in Imperial Gallon.
Sulphate of lime	70·994
Carbonate of lime	9·046
Carbonate of magnesia	5·880
Sulphate of magnesia	12·600
Sulphate of soda	13·300
Chloride of sodium	9·170
Chloride of potassium	·966
Carbonate of protoxide of iron	1·218
Silica	1·120
Total solid residue	124·294

In water obtained from a boring for water at Hinckley, where it stood at 630–80 feet, the depth being 705 ft. 2 in., there was a considerable amount of solid salts, and the salt spring or holy well owed its reputation to the same cause. The average analysis was:—

	Per 100,000 Gallons.
Lime	67·31
Soda	202·50
Magnesia	19·00
Sulphuric acid	295·60
Carbonic acid	16·67
Silicic acid	2·00
Chlorine	61·70
	664·78

It was combined thus:—

	Per 100,000 Gallons.
Sodium chloride	101·67
Sodium sulphate	340·39
Calcium sulphate	163·47
Magnesium sulphate	11·50
Magnesium carbonate	31·85
Silicic acid	2·00
	650·88
Add oxygen equal to chlorine	13·90
	664·78

The specific gravity was 1·0060. In 100,000 gallons there were 98 lb. of sulphate and carbonate of lime and 2½ lb. of chlorine gas. This compares well with the water which is used at Leamington Spa and Shearsby Spa in Leicestershire. It was limpid and clear, but brackish. By pumping the solids were reduced from 650 to 465. A similar water was met with at Bates's Brewery at 30 feet, containing 100 grains to the gallon.

In a boring at Ansty Paper Mill no water was met with below the gypsum. But in other cases wells 30–80 feet deep tapped an abundant supply, and water in one case burst through as soon as the gypsum was pierced, though marls above and below were dry. At Bagworth 7,200 gallons per hour were met with under gypsum at a depth of 197 feet, 100 gallons a minute at Desford at 109 ft. 8 in. (hardness 130°), and in South Leicestershire 17 gallons a minute.

The Upper Keuper Sandstone supply is not abundant and is hard. At Croft water issued constantly from a fissure at the bottom of a deep cutting, running constantly for eight months. A pump connected with a boring 130 feet deep yielded 100,000 gallons in ten hours, but the water was in this case very soft. Many wells in Leicester formerly derived a supply from this level up to 250,000 to 300,000 gallons per day. Thus, a well in Bond Street (Messrs. Fielding Johnson), sunk 151 feet, had water standing at 20 feet from the top, and similar wells were sunk in London Road by Messrs. Davis, and in Wharf Street by Messrs. Raven. In Churchgate (Messrs. Gimson) a well 70 feet deep had water standing at 55 feet from the bottom, and at St. Margaret's Works (Messrs. Corah) a well 84 feet had water at 72 feet from Upper Keuper Sandstones (26 feet thick).

No water is derived from the Tea-green Marls or Rhætics. Wells sunk to the latter have failed to meet with water. There is also too much iron pyrites in the latter to make the water palatable, except for mineral use.

The well-known Shearsby Spa derives its water from Keuper beds overlaid by Lias clays, etc. (perhaps 700 feet thick). It is very saline, brackish, but not acid. It has the smell of rotten eggs characteristic of sulphuretted hydrogen, and was used (in baths) for scorbutic diseases. It resembles the waters of Leamington,

Cheltenham, and Rugby. The specific gravity is 1·00469. It contains in an imperial gallon—

Carbonate of iron	traces
Carbonate of lime	9·743 grains
Carbonate of magnesia	6·246 ,,
Carbonate of soda	5·581 ,,
Sulphate of soda	128·989 ,,
Chloride of sodium	245·532 ,,
Chloride of potassium	traces
Hydrosulphide of sodium	·275 ,,
Iodine and bromine combined	traces
	396·366

The Old Spa on Humberstone Road, near the Wesleyan Chapel, derived its reputation from similar Triassic waters. Formerly there were salt springs at Weston, near Ingestre in Staffordshire, and brine at Branstone, near Burton, but there is no brine in the Leicestershire Trias.

The brine springs at Moira are thought to have derived their supply from Triassic beds overlying them. The Ashby baths were long noted for the waters procured from this source, and used for rheumatism, etc. In this water there is more bromine than in most Triassic waters, the springs at Cheltenham yielding 3·5 grains per gallon. The Moira brine contains per imperial gallon:—

	Grains.
Bromide of potassium and magnesium	8·0
Chloride of sodium	3700·5
Chloride of calcium	851·2
Chloride of magnesium	16·0
Chloride of potassium	·0
Iron as protochloride	trace
	4575·7

(*To be continued.*)

VII.—Optically Positive Cordierite.

By I. C. Chacko, B.Sc. (Lond.), B.A., A.R.S.M., A.R.C.S. (Lond.), State Geologist, Trivandrum, Government of Travancore, South India.

CORDIERITE was first found in Travancore at Teruwulla (lat. 9° 22′ N. and long. 76° 37′ E.) in a kind of diorite. In the hand-specimen the mineral appears as violet patches and spots. Monazite, magnetite or ilmenite, garnet and biotite with probably a little hornblende, occur in association with it. In the sections the mineral is found to contain numerous globular inclusions which are surrounded by pleochroic halos. The larger of these may be identified as monazite under the microscope. The mineral is itself pleochroic, light vibrating in the direction of the axis of mean velocity (Y) showing a pronounced violet tint. When light vibrates in other directions the plates do not show any distinct colour, but a faint yellow tint may be observed in some plates. When light vibrates in the direction of the Y axis the pleochroic halos round the inclusions disappear and assume the violet tint of the crystal plate. Cordierite is supposed to occur usually in metamorphosed sediments, and the pleochroic halos are regarded as due to the presence of

organic impurities. But a sedimentary origin is out of the question in the present case. It is held by some that pleochroic halos are due to the presence of radio-active substances. I kept an Ilford Empress photographic plate exposed in a dark box to a crushed sample of the mineral for more than twelve hours, but on development the plate did not show any indication of having been affected by the mineral.

Lamellar twinning is very common. But for its pleochroism the mineral may be mistaken for plagioclase on account of the similarity of its twinning and refractive index to those of felspar.

Cordierite is usually negative in optical character. But I think at least some of the crystals are optically positive in the present case. The optical character of a mineral is not an absolutely invariable property of it, especially when the axial angle lies in the neighbourhood of 90°. When the angle is nearly 90°, a slight variation in it may change the character of a mineral from negative to positive or from positive to negative. Slight variations, and in some cases large variations, in the axial angles of minerals are very common. In the case of cordierite the axial angle is very nearly 90°, and a change in optical character may be expected. At the same time it must be remembered that the very fact that the angle is nearly 90° makes it difficult to distinguish the acute bisectrix from the obtuse with an ordinary petrological microscope, and on this account there is possibility of error in the observations. Minerals of double optical character are not, however, unknown. Among biaxial minerals, anthophyllite, penninite, and kammererite are examples.

Owing to the presence of inclusions and the intimate association of the mineral with other minerals, it is not easy to determine its density with accuracy. In a series of separations of a finely crushed sample with Klein's solution, particles of the violet mineral were found to sink at various stages of the density of the solution between 3·00 and 2·60 approximately. The denser particles are regarded as having inclusions or as associated with other heavy minerals. For the analysis given below such particles of the violet mineral as floated in a heavy solution in which a quartz crystal would just sink were selected. An analysis of such selected grains of the cordierite gave the following results:—

Water	1·74
Silica	49·74
Ferric oxide	5·65
Ferrous oxide	3·00
Alumina	35·21
Lime	1·05
Magnesia	4·30
	100·69

What strikes one first in this analysis is the high percentage of ferric oxide. Of the eleven analyses given by Dana of samples of cordierite from various localities, nine do not give any ferric oxide at all, while two give only 0·63 and 0·38 per cent of ferric oxide respectively. On the other hand, the percentage of ferrous oxide is low in the present analysis. Magnesium replacing ferrous iron in

cordierite, a decrease in the latter is to be accompanied with an increase in the former. In the present case the percentage of magnesia is also low. The ferrous equivalent of the sum of ferrous oxide and magnesia does not fall below 22 per cent in the analyses given by Dana, while it is as high as 27 per cent in the case of Finland cordierite. The percentage of alumina usually does not go beyond 33, whereas in the present case it is as high as 35·2. The other constituents remain within normal limits. If we may rely on the accuracy of this analysis, this cordierite is of a peculiar constitution. It must, however, be remembered that there is just a possibility of error in the determination of the two oxides of iron.

The positive character of some of these cordierite crystals is confirmed by the observations of Mr. G. dep. Cotter, Assistant Superintendent, Geological Survey of India. His remarks on the mineral are given below:—

"In the slide which Mr. Chacko now sends I find that one section of cordierite gives a positive figure and one section gives a negative figure. I have also found a positive figure from the cordierite from Vizagapatam, 16/189. This is probably due to the increase of the value of $2V$ beyond 90° (see Iddings). $2V$ in cordierite is very variable, and the lower the refractive the greater is $2V$. The mineral sent now by Mr. Chacko has been tested by the method of Schroeder Van der Kohlk, and its refractive index lies between nitrobenzene and cedar oil, and it gives reds and blues for a mixture of both. Therefore its refractive index is about 1·53, that is, fairly low. We may then conclude that $2V$ is probably large. In fact, I agree with what Mr. Chacko suggests, and think it might be worth publishing if he cares to do so. There is no section in the slide suited to the actual measurement of $2V$."

NOTICES OF MEMOIRS.

I.—British Association for the Advancement of Science, Eighty-sixth Annual Meeting, Newcastle-upon-Tyne, September 6–8, 1916.

List of Authors and Titles of Papers read in Section C (Geology).

Presidential Address by *Professor W. S. Boulton.*

Professor G. A. Lebour.—Address on the Local Geology.

Dr. D. Woolacott.—Some Notes on the Permian of Durham.

Dr. G. Hickling.—Underground Contours of the Black Mine.

Professor W. G. Fearnsides.—Underground Contours of the Barnsley Mine.

Joint Meeting with Section E in the Room of Section C.

Dr. A. Wilmore.—The Physical Geography and Geology of the Northern Pennines.

Professor W. G. Fearnsides and *Dr. P. G. H. Boswell.*—Note on the Occurrence of Refractory Sands and Associated Materials occurring in Hollows in the Surface of the Mountain Limestone District of Derbyshire and Staffordshire.

Dr. P. G. H. Boswell.—Geological Characters of Sands used in Glass Manufacture.

Reports of Research Committees :—

Dr. W. T. Gordon.—Report of Committee to investigate the Flora of Lower Carboniferous times as exemplified at a newly discovered locality at Gullane, Haddingtonshire.

Professor T. Johnston.—The Old Red Sandstone Rocks of Kiltorcan, Ireland.

Dr. W. Mackie and *Dr. J. Horne.*—Report of Committee to excavate Critical Sections in Old Red Sandstone Rocks at Rhynie, Aberdeenshire.

Dr. R. Kidston, F.R.S. and *Professor W. H. Lang, F.R.S.*—Description of a new fossil plant, *Rhynia Gwynne-vaughani* found at Rhynie.

Joint Meeting with Section B in the Room of Section C.—On the investigation of the chemical and geological characters of different varieties of coal, with a view to their most effective utilization as fuel, and to the extraction of by-products.

Discussion opened by *Professor G. A. Lebour*; and followed by *Professor W. A. Bone, F.R.S., Dr. A. Strahan, F.R.S., Dr. J. T. Dunn*, and others.

Mr. Joseph Lomax.—Microscopical Examination of Coal as a means of Identification and Correlation of Seams.

Mr. Leonard Hawkes.—The Acid Rocks of Iceland.

Dr. Alexander Scott.—The Petrology of the Arran Pitchstones.

Dr. J. W. Evans.—Methods of representing Geological Formations and Structures in black and white on Maps.

Mr. Leonard Hawkes.—The Acid Rocks of Iceland.

Dr. Alexander Scott.—The Petrology of the Arran Pitchstones.

E. Heron-Allen.—The Application of X-rays to the Determination of the internal Structure of Microscopic Fossils, especially with regard to the Dimorphism of the Nummulites.

Professor W. W. Watts, F.R.S.—Geological Photographs.

Papers read in other Sections bearing on Geology.

Section D.—Zoology.

Professor A. Meek.—The Scales of Fishes and their value as an aid to investigation.

Section E.—Geography.

Dr. W. S. Bruce.—The Weddell Sea.

Section H.—Anthropology.

Professor W. J. Sollas, F.R.S.—A Sub-Crag Flint Implement.

Dr. Marrett.—Recent Archæological Discoveries in the Channel Islands.

Section K.—Botany.

Joint Meeting with Section C in the Rooms of Section K (Botany).

Discussion on the bearing of Botanical Science on Coal, to be opened by *Dr. Marie C. Stopes.*

Professor R. H. Yapp.—The Origin of Salt-marsh Pans.

Discussion on the Utilization of Waste Lands, introduced by *Professor F. W. Oliver*, and including the following short papers:—

P. A. Martineau.—The Afforestation of Pit Banks: Discussion.

Professor F. W. Oliver.—Maritime Wastes.

Professor W. B. Bottomley.—Waste Moorlands.

Professor J. Lloyd Williams.—Reclamation of Peaty Soils in Carnarvonshire.

Dr. W. G. Smith.—Utilization of Northern Mountain and Heath Land.

II.—Some Geological Characters of Sands used in Glass Manufacture. By P. G. H. Boswell, A.R.C.Sc., D.Sc., F.G.S.

At a time when it is necessary to know the extent and value of our national resources of sands suitable for various industrial purposes, including glass manufacture, it is especially desirable that we should realize the particular properties of such sands and the geological conditions under which the deposits occur in the field.

1. In chemical composition, for all general purposes of glass-making, the sand should contain a very high proportion of silica, if possible over 99 per cent. The percentage of iron (estimated at Fe_2O_3) should be as low as possible. For optical glass, table-ware ('crystal'), etc., it should not rise above 0·5 per cent; for laboratory-ware, globes, and all second-grade glass-ware, a percentage up to 0·02 is permissible; for plate and window-glass and good white bottle-glass, the proportion may reach 0·3 or 0·4 per cent; and for rough bottle-glass and other similar work, a limit of 2 per cent may be admitted. For refractory glass, such as that used for thermometers, gauges, certain laboratory-ware, etc., it is an advantage to find a sand bearing 4 per cent or more of alumina. Unfortunately, most British sands bearing alumina carry also iron and other undesirable impurities. Other bases such as lime, magnesia, titanium, and alkalies, should, if present at all, exist only in negligible quantities. In the analyses the loss on ignition should also appear; it yields an indication of the amount of water and organic substances present. The latter are not objectionable as they usually 'burn out'.

The analysis of one of the best British glass-sands, a sample of Lower Greensand from Aylesbury, indicates SiO_2, 99·80 per cent; Al_2O_3, 0·32 per cent; Fe_2O_3, 0·03 per cent; loss on ignition, 0·22 per cent; total, 100·37 per cent. With this may be compared a well-known German glass-sand from Lippe: SiO_2, 99·88 per cent; Al_2O_3, 0·18 per cent; Fe_2O_3, 0·02 per cent; loss on ignition, 0·21 per cent; total, 100·29 per cent.

2. For all but the highest quality glass, where the cost of crushing the raw material to a fine even state, with suitable subsequent treatment, is not prohibitive, the mechanical composition is of the utmost importance. The sand used should, if possible, be perfectly graded, that is, it should be composed of grains all of the same size. Such perfection of grading is not attained as a result of natural agencies; the best-graded natural deposits contain over 90 per cent of grains of one grade, which, for glass-making purposes, is preferably

the medium-sand grade (diameter $> \frac{1}{4}$ and $< \frac{1}{2}$ mm.). A high percentage of the fine-sand grade (diameter $> \frac{1}{4}$ and $< \frac{1}{16}$ mm.) would be even more preferable, but suitable sands with a high proportion of this grade are not of common occurrence in this country. Coarser sand-grains are not desirable, and, if present, should be removed by sieving. Very fine sand, silt, and clay-grades are inimical, and must be removed by washing.

3. The mineral composition should be as simple as possible, contain only quartz, or quartz and felspar, and the heavy detrital minerals present should be small in quantity and simple in composition.

The treatment of sands (whether chemical, to remove iron, or mechanical, to ensure good grading) often involves prohibitive expense. It is therefore of considerable importance to look into the geological conditions under which desirable glass-sands occur. We may thus receive clues to the existence of further supplies by knowing the kind of deposits in which they are met, and the special conditions under which we may expect to find them. The important supplies of glass-sands occurring in Western Europe are associated with rafts of braunkohle in beds of Miocene age; Hohenboka sand, of the same age, containing carbonaceous layers; Fontainebleau sand, in Upper Oligocene deposits, with lignites; Inferior Oolite sands in the Yorkshire and Northampton districts, containing planty matter and roots; Berrythorpe sand (Callovian), containing carbonized woody material and peaty matter; Aylesbury and Leighton Buzzard sands (Lower Greensand) with peaty bands; Headon Hill and Bagshot, from Alum Bay, Wareham, and other places (Eocene, etc.), interbedded with lignites. Numerous other examples may be adduced. Attention also may be drawn to the very pure sandstones of the Coal-measures, associated with coal-seams, and to the white sandstones found with the Brora coals of Scotland (Callovian). The bleaching of the reddish sands, for a foot or two in depth, upon our heaths, is a similar phenomenon. In each case the freedom from iron may be attributed to the reducing action of the planty matter, in changing the ferric salts to the more soluble ferrous state, when they are more easily removed by percolating waters.

The beds of white sand seem always to be of limited thickness, and frequently to be laid down under lagoon or estuarine conditions favouring the development of plant life. Cementation is objectionable, either because of the introduction of impurities or because of the cost of subsequent crushing. It is desirable, therefore, that the deposits should be incoherent. The most widely used sands are thus those of comparatively late geological age. Most of them occur in Tertiary deposits, but some are Cretaceous in age. A strong tendency, also, exists for the simplification in mineral constitution (due to elimination of more easily decomposable minerals) and greater perfection of grading in the later geological sediments—a result of their constituents having passed through many geological cycles.

[This, and the two following Notices, are *Abstracts* of papers read in Section C (Geology), British Association, Newcastle-on-Tyne, September, 1916.]

III.—The Acid Rocks of Iceland. By Leonard Hawkes, M.Sc.

An account was given of the preliminary results of an investigation of the Tertiary Acid series. It is known that these rocks are widely developed in East Iceland, but hitherto definite information as to their extent, nature, and mode of occurrence has been lacking. Whilst they have been stated to be partly intrusive and partly extrusive,[1] it has generally been accepted that they are dominantly intrusive in character,[2] a view which has probably been influenced by the general intrusive nature of the British Tertiary acid rocks.[3]

The main exposures of acid rocks in East Iceland from Borganfjord to Bernfjord have been studied in the field. Evidence was brought forward to show that these rocks are in the main extrusive in character. In places the acid series is at least 2,000 feet in thickness. Tuffs and sphærolitic liparites and obsidians are very common. The author holds that the old view, that the acid rocks are dominantly intrusive, being thus marked off from the basic rocks, is incorrect. Tertiary volcanic activity was similar to that which has obtained in Iceland in post-Glacial times, when acid rocks have been extruded along with the basic, but in a smaller amount. Acid eruptions seem to have taken place almost continuously during the building up of the Tertiary plateau. The uneroded character of the liparite lava-streams shows how rapidly the successive basalts which submerge them were poured out, and this throws some light on the problem of the intrusive or extrusive origin of the Antrim rhyolites.

Since the close of the Tertiary volcanic period enormous denudation has obtained, and the varying resistance offered to erosive agents by acid and basic rocks has produced some remarkable effects.

Thoroddsen has described some peculiar streams of acid rocks which he regards as post-Glacial lava-flows, formed by the extrusion of liparite blocks in a half-melted condition from the mountain sides. The most noteworthy of these occurs in the Lodmundarfjord. The rocks of the district are Tertiary bedded basalts with the exception of an acid series, contemporaneous with the basalts, revealed in a huge cirque excavation in a side valley. The valley is full of a chaotic assemblage largely composed of sphærolitic liparite reaching down from the cirque (Skúmhöttur) on the bottom of the main valley (Lodmundarfjord).

The author holds that these blocks do not represent a lava-stream but a moraine. All the rocks of the stream occur in situ in the Skúmhöttur mountain. The theory of morainic origin has been previously rejected, partly on account of the reported exclusive liparite composition, where a mixture of acid and basic rocks would have been expected. It was found, however, that the stream is not exclusively composed of acid types, though dominantly so. The

[1] Th. Thoroddsen, "Island: Grundriss der Geographie und Geologie," No. 152: Pet. Mitt., 1905, p. 269.

[2] Ibid., p. 232. H. Pjeturss, "Island": Handbuch der Regionalen Geologie, 1910, p. 5. C. W. Schmidt, "Der Liparite Islands in geologischer und petrographischer Beziehung": Zeit. Deutsch. geol. Ges., vol. xxxvii, p. 783, 1885.

[3] Sir A. Geikie, *Ancient Volcanoes of Great Britain*, vol. ii, p. 364, 1897.

large proportion of liparite present results from its lesser resistance to ice-erosion compared with basalt, whereby the huge cirque has been excavated where the acid rocks occur, and the material deposited to form the present remarkable stream. It has also been objected that none of the blocks are ice-scratched, but this is not to be expected owing to the exceptional fissility of liparite and its rapid degradation under weathering influences. The author has never seen an ice-scratched boulder in Iceland.

IV.—The Petrology of the Arran Pitchstones. By Alexander Scott, M.A., D.Sc.

ALTHOUGH the Arran pitchstones are so widely known, no extensive examination of them has ever been made. The intrusions, which number about eighty, may be divided into the following groups:—

1. Non-porphyritic glasses with abundant microlites which are generally hornblende. These are found chiefly in the district round the coast, and include the Corriegills and Monamore Glen occurrences.

2. Pitchstone porphyries with large phenocrysts of quartz and felspar and scarce augite, and with hornblende microlites. This group includes many of the dyke-rocks intrusive into the Goatfell granite.

3. Pitchstone porphyries with phenocrysts of felspar and pyroxene and subordinate quartz. The pyroxene includes both augite and enstatite, and scarce crystals of an iron-rich olivine also are found. Microlites of pyroxene and of hornblende occur. This group is typical of the intrusions of the south end of the island.

4. More basic type with scarce phenocrysts and great abundance of pyroxene microlites. This group is represented by two occurrences in Glen Cloy and several around the great Tertiary volcanic vent.

Analyses have been made of each type, and the results show the existence of considerable variation in composition. An attempt has been made to determine the cooling histories from the examination of the field-relations and microscopic structures of the various types, and also to indicate the conditions which are responsible for such a large development of glassy intrusive rocks.

REVIEWS.

I.—The Later Stages of the Evolution of the Igneous Rocks. By N. L. Bowen. Journ. Geol., Supp. to vol. xxiii. pp. 91. 1915.

THE determination of the processes whereby the various types of igneous rock have been derived by differentiation from a few relatively simple magmas has long been, and still is, one of the chief problems of petrology. Of the hypotheses which have been advanced in order to explain differentiation, several have been discredited and are seldom advocated nowadays; thus "Soret's principle", to which

attention was first called by Lagorio, has now been generally abandoned, mainly owing to the criticisms of Becker, Harker, and others. The theories still under discussion include those based on assimilation, pressure phenomena, the action of vapours, liquation, and fractional crystallization. Loewinson-Lessing held that the solution of foreign material was the chief factor, a view also held by Johnston-Lavis and, in a modified form, by Daly. The possible influence of pressure has been indicated by Schweig, while Michel Lévy favoured the activity of the volatile constituents of the magma as the most potent operator in producing heterogeneity. The process of liquation, first advanced by Durocher, has received many supporters, including Daly, but fractional crystallization, as suggested by Becker, has also attracted much favour. In the paper under review this last hypothesis is advocated, the arguments being based on recent synthetic work on the equilibrium of mineral systems.

While in the earlier investigations the systems involved were simple, it has now been found possible to examine some, such as diopside-forsterite-silica, anorthite-forsterite-silica, and diopside-plagioclase, which approximate to certain simple types of igneous rocks. Bowen summarizes the information which has been obtained from these synthetic investigations, and bases on them a systematic theory of petrogenesis, with fractional crystallization, the sinking of crystals, and the squeezing out of the residual magma as the chief factors of differentiation. A basaltic magma is taken as the starting-point, and it is shown that the various ways in which this can crystallize may give rise to a sequence from granite to peridotite.

While the rapid cooling of such a magma produces a simple basalt, slow cooling, accompanied by the sinking of the early-formed crystals of pyroxene and lime-plagioclase, results in the enrichment of the upper liquid layers in alkali-felspar, and in their subsequent consolidation as diorite. With still slower cooling the residual material crystallizes as quartz-diorite, granodiorite, or granite. If the cooling history is such that the plagioclase crystals are zoned, the salic material may be found filling the interstices between the earlier minerals. If pyroxene alone separates out, the lower layers are composed of the "anchi-monomineralic" rock pyroxenite; if olivine alone sinks before resorption occurs, the resulting rock is dunite; if pyroxene and olivine separate out together, or if the olivine is partly resorbed after sinking, various types of peridotite may be formed. The separation of these minerals which are poor in silica greatly enriches the upper layers in the latter oxide, which may, if the cooling has been sufficiently protracted, finally crystallize as quartz.

Nevertheless, quartz is so abundant in igneous rocks that the early separation of olivine cannot alone be held responsible for its presence. The commonest ferromagnesian mineral in the acid rocks is biotite, and as this is relatively poor in silica Bowen holds that its early formation is responsible for the existence of much of the quartz. There is here a discrepancy between the synthetic work and the natural rocks, as the salic pole of the differentiation in the former is a pyroxene-bearing granite, and in the latter a biotite or hornblende

granite. This is explained as "the result of an increasing concentration of the volatile constituents", which lowers the temperature of consolidation and allows the formation of the water-bearing minerals, biotite and hornblende.[1]

The origin of the alkaline rocks is traced to the influence of the water, fluorine, and other mineralizers. During the crystallization of biotite-granite, if the residual liquid be separated in some way from the already formed biotite and quartz, it must have a greatly increased concentration, not only of such volatile substances as H_2O, Cl, SO_3, CO_2, and so forth, but also of such alkali silicates as albite, orthoclase, nephelite, and kaliophilite; and the latter molecules may combine with the former to give the felspathoids. Thus the separation of the alkali-syenites may occur at any of the stages at which the formation of biotite and quartz is possible, that is, at any stage between diorite and granite. While this line of descent results from the maximum activity of the volatile constituents, there is an alternative which, in its earlier stages at least, represents the result of the minimum activity. If a gabbro magma be impoverished in water and similar constituents, the formation of biotite is inhibited, and the proportion of such silicates as orthoclase increased, so that the latter separates out along with lime-plagioclase, giving rise to an essexite or similar rock. Even in this case, however, the ultimate differentiate may be nephelite-syenite, if at any stage there is a concentration of the mineralizers. Thus we have the two alternate lines of descent of the alkaline rocks, the intermediate stages between gabbro and nephelite-syenite being, in the one case diorite and normal syenite, and in the other essexite and augite-syenite.

Leucite-bearing rocks are supposed to be formed in a similar fashion, and the fact that this comparatively rare mineral is practically confined to hypabyssal and effusive rocks is considered to be due to the facilities, which the latter often have, for the escape of mineralizers, thus allowing the potassium salts to consolidate as leucite instead of the more complex minerals such as mica.

The fact that the theory has a sound experimental basis renders it less liable to criticism than most previous attempts. It must be remembered, however, that it is only the early stages, namely, the derivation of ultrabasic rocks on the one hand and of the diorite and certain syenites on the other, from the primary basaltic magma, that has been subjected to verification in the laboratory. Experimental difficulties have hitherto precluded any systematic investigation of water-bearing magmas, and hence comparatively little is known concerning the formation of the micas and other hydrated minerals. Recent work has demonstrated beyond all doubt the practical absence of eutectics in basaltic rocks, and has shown that the presence of solid solution between two or more of the constituents increases the variation in the possible results of the consolidation. Hence it is very unsafe to prophesy the results of crystallization where the degree of solid solution is immensely greater, as in the case of the micas and the amphiboles. Owing to this complex isomorphism,

[1] Cf. Allen & Clement, *Amer. Journ. Sci.*, ser. IV, vol. xxvi, pp. 101–18, 1908.

this part of the theory is tentative and the details are liable to modification.

When the theory is considered in relation to the actual intrusion or extrusion of the rocks, several difficulties arise. The first of these is concerned with the sequence of igneous intrusion. Bowen considers that the intrusion of basic into acid material is due to movements during cooling, and that the absence of granitic upper layers is sometimes due to denudation. In the "Younger Igneous Rocks" of the Scottish Highlands the sequence is from peridotite to granite, with the acid rocks always intrusive into the basic. As several of the former are found in contact with the schist roof, the acid layers cannot have been denuded away, and it is difficult to understand the mechanics of the differentiation and intrusion, particularly if the former be considered to have occurred in situ. A related point is concerned with the intrusion of batholiths, as the theory takes no account of the material into which the batholith is intruded. It also seems to the writer that some of the later igneous rocks must partly owe their composition to refusion, and possibly absorption, and that they are not all direct differentiates of a primary basaltic magma. Yet, on the whole, the theory may be regarded as the most satisfactory advanced so far, particularly with regard to those parts of it which do not depend on any great extrapolation from the synthetic work. A. S.

II.—The Pliocene Mollusca of Great Britain, being supplementary to S. V. Wood's Monograph of the Crag Mollusca.[1]

By F. W. Harmer, F.G.S., F.R.Met.S., etc.

THE rich remains of Pliocene Mollusca which characterize the Crag deposits of East Anglia have long been familiar to the palæoconchologist through Searles Wood's classic memoir on that subject, which was issued in parts by the Palæontographical Society between the years 1848 and 1882. Few fossiliferous regions have been so popular with the collector and student as the counties of Norfolk, Suffolk, and Essex, which have yielded the Crag fauna, doubtless by reason of their easy accessibility from London and the numerous open crag-pits from which specimens could readily be obtained.

It has been inevitable, therefore, since the completion of Wood's work, now more than thirty years ago, that a large amount of further material has been acquired, the study of which has rendered necessary the recognition of many new forms and a revision of the older nomenclature. This is the special task which the author of the present memoir has set himself to accomplish, and for which, we think, he is particularly well qualified to undertake. It is interesting to note that Mr. Harmer was the great friend of Searles Wood, the younger, and a co-worker with him in unravelling the history of the Crag formations, he himself becoming the author in later years of many valuable contributions on the same subject, so that at the present day he may be regarded as one of our best authorities on the Pliocenes

[1] Pt. i, pp. 1–200, pls. i–xxiv; pt. ii, pp. 201–302, pls. xxv–xxxii. Published by the Palæontographical Society, 1914, 1915. (Pt. iii now in the press.)

of this country. He has, moreover, collected from the more important Continental deposits of Pliocene age, and has made himself familiar with the priceless collections of later Tertiary Mollusca preserved in the Museums of France and Italy.

The particular material on which this memoir is based was obtained from excavations carried out at Little Oakley, near Harwich, which has furnished a prolific molluscan fauna of Red Crag or 'Waltonian' age containing littoral, southern, and some northern species.

The two parts, now issued, comprise together 302 pages of text and 32 plates. Brief notices of these have already been published (GEOL. MAG., 1914, p. 227; 1915, p. 565; and Ann. Mag. Nat. Hist., ser. VIII, vol. xiii, p. 604, 1914), but, on account of the great importance of the work both to the palæontologist and the collector, it is thought that a further record of so valuable a work may be acceptable. In the early pages of the memoir the author introduces us to the non-marine shells of the Crag period under the groups "Terrestrial" and "Aquatic", comprising nearly fifty species, of which about one-fourth are regarded as extinct, while all have been previously described elsewhere. The distribution of these forms is set out in a tabulated scheme showing that they are best represented in the Norwich Crag, fewer species occurring in the Red Crag, while only three have been recognized in the Coralline Crag.

The author next proceeds to the consideration of the marine Gastropoda, of which over three hundred species and varieties are at present discussed, more than eighty being regarded as new. These species are treated under the following genera and subgenera: *Trivia*, *Voluta*, *Ancilla*, *Terebra*, *Columbella*, *Astyris*, *Cassidaria*, *Cassis*, *Semicassis*, *Rostellaria*, *Rimella*, *Nassa*, *Desmoulea*, *Buccinum*, *Liomesus*, *Purpura*, *Stenomphalus*, *Triton*, *Murex*, *Ocinebra*, *Urosalpinx*, *Trophon*, *Meyeria*, *Searlesia*, nov., *Parasipho*, *Anomalosipho*, *Volutopsis*, *Beringius*, *Neptunea*, *Fusus*, *Sipho*, *Pleurotoma*, *Hemipleurotoma*, *Clavatula*, *Genotia*, *Pseudotoma*, *Borsonia*, *Oligotoma*, *Drillia*, *Spirotropis*, *Clathurella*, *Bellardiella*, *Mangilia*, *Hædropleura*, *Raphitoma*, *Bela*, and *Taranis*.

Clear diagnostic characters are furnished of each species or variety, followed by full information respecting geological and geographical distribution. It is noticeable that a few of the generic names have been attributed to pre-Linnæan authors, whereas, according to the laws of zoological nomenclature, the author should be quoted who first adopted such from the time of Linnæus and upwards. Therefore, we think it preferable to write *Terebra* (Adanson, 1757), Lamarck, 1799; *Fusus* (Klein, 1753), Lamarck, 1799; and so on. Again, some of the generic names appear to be preoccupied in other sections of zoology, as, for instance: *Triton*, of De Montfort, 1810, which had been previously used by Linnæus for one of the Cirripedia, and hence we think Schumacher's *Lampusia* should take its place; *Meyeria*, of Dunker & Metzger, 1878, was applied by McCoy to a Crustacean in 1849, and must, therefore, be replaced by Norman's *Metzgeria* of 1879; Klein's *Sipho*, adopted by Mörch in 1852, differs from that of Fabricius of 1823, and thus, according to the late G. F. Harris (Cat. Australasian Tert. Moll. Brit. Mus., 1897, p. 152), Beck's *Tritonofusus*

of 1847 should be accepted; lastly, Bolten's *Turris* of 1798 has priority of *Pleurotoma*, of Lamarck, of 1799. Few systematic works on palæontology are entirely free from blemishes connected with nomenclature, and it is only by persistently calling attention to them that we may hope to guard against similar errors in the future. This criticism, therefore, is offered in no captious spirit, being considered to detract in no way from the great excellence of the work which, when completed, will rank as a valuable guide and reference book to the history of the later Tertiary Mollusca of this country. Special mention should be made of the beautiful photographic figures prepared by Mr. J. Green, which form the plates that adorn the monograph. Not only are the British Crag shells figured in this way, but illustrations are frequently given side by side of recent and foreign specimens for purposes of comparison. Thus, the author attains an accuracy in his determinations which will be of inestimable importance, not only to the palæontologist but also to the collector, who will almost be able to name his shells without reference to the text.

The work appears to be a long way from completion, but we earnestly trust that, when the last part is in preparation, the author will provide us with an ample index so that every specific and generic name used, whether in synonymy or elsewhere, shall be brought out alphabetically. With such an adjunct the utility of this valuable memoir will be very greatly enhanced.

III.—Agricultural Geology. By R. H. Rastall, M.A. 8vo; pp. x + 332. Cambridge University Press, 1916.

THE place occupied by geology in an agricultural curriculum varies so much in different universities and other institutions that the task of writing a suitable textbook is a peculiarly difficult matter, and we welcome this conspicuously successful attempt by so competent a geologist as Mr. Rastall to fill a gap that has long existed. About half the text is taken up by chapters on Minerals and Rocks, Weathering, Transport and Corrasion, Sediments, Superficial Deposits, and Soils, including most of those matters that are of primary importance from an agricultural point of view. These are models of their kind, as might be expected from one of our leading petrologists. The literature on soils is so scattered, and so little has been attempted in this country by way of soil surveys, that all those concerned with scientific agriculture are indebted to the author for his able correlation of the chief available facts. He regrets in his preface that considerations of space have prevented the inclusion of full details on the subject of mechanical soil analysis, but we hope these will find a place in the next edition, though of course aware that they have been ably treated by Mr. A. D. Hall in his well-known works. The essential facts of water supply and drainage are clearly set forth in chapter vii, the page on "dew ponds" being of particular interest. Then follows a chapter on geological maps and sections, which would be much improved by a few cuts to illustrate the chief kinds of map in common use. The rest of the book is mostly occupied by well-balanced chapters on stratigraphy, the one

thing lacking here being illustrations of a few leading fossils, just sufficient to help the student to recognize the chief fossiliferous strata as met with in the field. The last chapter, contributed by Dr. F. H. A. Marshall, embodies a most interesting and valuable summary of our knowledge of the geological history of the Domestic Animals. We only wish this chapter could have been more fully expanded. In conclusion, we congratulate Mr. Rastall on his admirable and luminous textbook, which should be in the possession of every teacher and serious student of agriculture.

J. R. A.-D.

IV.—The Purbeck Charas.

AT last we are promised some definite information about the interesting series of *Chara*, so common in the Purbeck cherts. Hitherto the nature of the matrix has only permitted a study of sections of these plants allowing of imperfect examination. But the labours of Messrs. Clement Reid & James Groves resulted in the finding of *Chara* remains in a close-grained limestone, which permitted a fresh method of treatment. On treating pieces of limestone with a steady drip of slightly acidulated water the results were surprising even to the experimenters. The irregular mineralization of the limestone allowed the dripping water to rapidly attack the pure calcite and to leave the silicified matter standing in relief. As the *Characeæ* proved to be not pure calcite they were among the standing forms after treatment. And the authors have not only been able to obtain reliefs of fruits and stems, but even, in many cases, completely to remove fruits and stems from the matrix. The amount of new material is so great that there may be seven or even eight species of four genera. But they are so broken up and entangled that it will take much research to work them out properly. The most abundant form, however, is fairly well known, and Messrs. Reid & Groves have described it as *Clavator*, n.g., in Proc. Roy. Soc., B., vol. lxxxix, pp. 252–6, pl. viii, 1916; no trivial name is given, nor is any type quoted, unless Messrs. Reid & Groves wish it to be understood that Saporta's species (the only one mentioned) is to be so regarded. The editor is at fault in passing this omission. The paper is of remarkable interest and importance.

V.—The Correlation of the Pre-Cambrian Rocks of the Region of the Great Lakes. By A. C. Lawson. Bull. Dep. Geol. Univ. California, vol. x, No. 1, pp. 1–19.

IN this paper the author endeavours to draw up a correlation table for the pre-Cambrian rocks of Canada, based on the hypothesis that there have been in the region named two and only two great periods of granitic intrusion, each followed by its concomitant uplift and denudation, this constituting a major unconformity. The classification on this basis when reduced to its simplest terms is as follows: (1) Ontarian system, including the Coutchiching, Keewatin, and Grenville series. (2) Laurentian revolution, that is, the intrusion of the granite batholiths. (3) Epilaurentian interval, when the

foregoing underwent extensive denudation. (4) Huronian system, including the Bruce and Temiskamian series. (5) Algoman revolution: the intrusion of the Algoman granites. (6) The Eparchæan interval of denudation. (7) This was followed by the deposition of the Animikian and Keweenawan series, forming the Algonkian system, which the author prefers to regard as being the base of the Palæozoic. This concise statement will do much to simplify and render clear a subject in which much confusion has hitherto prevailed, largely owing to an unnecessarily cumbrous nomenclature, but partly also due to uncertainty in the correlations.

VI.—Muschelkalk Ichthyosaurs.—Von Huene's manuscript on the Muschelkalk Ichthyosaurs, dated autumn, 1913, has just appeared in *Palæontographica*, vol. lxxii, pt. i, June, 1916. The work consists of 68 pages, 7 plates, and 96 text-figures, and is of the greatest use for comparison and study. Von Huene describes the genera *Mixosaurus*, *Cymbospondylus*, *Shastasaurus*, *Pessosaurus*, and a new genus *Pachygonosaurus*, founded on a few vertebræ in the Berlin Museum, indicative of two species to which no trivial names are assigned. The illustrations are abundant and good.

CORRESPONDENCE.

ROPY SURFACES OF LAVA IN ICELAND.

Sir,—In last month's Geological Magazine, writing of the ropy lava surfaces so characteristic of large areas of the Icelandic deserts, I remarked on never having seen similar surfaces in the Tertiary series of Iceland, and added that they do not seem to have been noted in the British Isles.

I find, however, that basalts with ropy surfaces were observed in the Færöe Islands by Sir George Mackenzie and described by him to the Edinburgh Royal Society in 1812. Mackenzie's paper (Trans. Roy. Soc. Edin., vol. vii, p. 213, 1814) contains a natural size illustration of ropy basalt. He writes: "The surfaces of many lavas which I passed over in Iceland were not unlike coils of rope or crumpled cloth, an appearance which we should expect to be assumed by any viscid matter in motion. On our first visit to the island of Naalsöe we observed the surface of a bed of amygdaloid, which had been exposed to a considerable extent by the removal of the bed above, exhibiting an exact picture of the lavas I had seen in Iceland" (p. 221). Mackenzie states that whatever doubt may have previously existed in his mind as to the igneous origin of the 'trap' was dissipated by the discovery of these ropy surfaces.[1]

Leonard Hawkes.

Glasgow.

[1] In reference to the footnote to my paper, Geol. Mag., Sept. No., p. 390, I find that Dr. Pjetursson now regards his "Graa Etage" of Middle Northern Iceland as of Post-Tertiary age. This view presents difficulties, and I prefer to hold to his former idea as there indicated. The doubt I expressed relates, not to the Tertiary age of the "Graa Etage", but to the adequacy of the evidences therein of a general "glacial period".

THE LATE PROFESSOR JAMES GEIKIE.[1]

SIR,—A biography of the late Professor James Geikie is now in course of preparation, and the work would be greatly facilitated if those who have letters or communications of general interest from him would kindly forward these to me at the Royal Scottish Geographical Society's Rooms, Synod Hall, Castle Terrace, Edinburgh. They will be carefully preserved and returned after being copied.

EDINBURGH, MARION I. NEWBIGEN.
September 4, 1916.

OBITUARY.

JAMES DALLAS, F.S.A.Scot.

BORN 1853. DIED SEPTEMBER 12, 1916.

WE regret to record the death, in his 63rd year, of Mr. James Dallas (formerly curator of the Albert Museum, Exeter), which occurred on September 12, at Bampton, Oxon. James Dallas, F.S.A.Scot., was the son of the late W. S. Dallas, F.L.S., for so many years Assistant Secretary to the Geological Society of London.

CHARLES DAWSON, F.S.A., F.G.S.

BORN JULY 11, 1864. DIED AUGUST 10, 1916.

GEOLOGISTS and archæologists alike mourn the early death of Mr. Charles Dawson, of the Castle Lodge, Lewes. For thirty years he had been one of the most active students of the geology and antiquities of Sussex. To a capacity for taking pains, with endless patience, he added a sharpness of sight that never overlooked anything of importance; and he was not only in close touch with all workmen in his district who might make accidental discoveries, but was also in constant friendly communication with a wide circle of professional scientific men who helped him to make the best use of his material.

Charles Dawson was born at Fulkeith Hall, Lancashire, fifty-two years ago, the son of Mr. Hugh Dawson, barrister-at-law. Most of his early life was spent at St. Leonards-on-Sea, and he was educated at the Royal Academy, Gosport. He began to study law in 1880, and from 1890 until the time of his death he practised as a solicitor at Uckfield. There he held several public appointments, and won the highest esteem of all who were associated with him. His duties were many and arduous, and science was the recreation of his leisure hours.

From early boyhood Mr. Dawson had been interested in natural history and antiquities, and he began to collect Wealden fossils from the quarries and cliffs round Hastings. He soon attracted the notice of Mr. S. H. Beckles, F.R.S., who was then spending his last years at St. Leonards. He was thus helped and encouraged to collect Dinosaurian remains in a systematic manner; and he met with so much success that by 1884 he had made a valuable collection which

[1] For a brief account of Professor James Geikie and his works, see "Eminent Living Geologists" (GEOL. MAG., N.S., Dec. V, Vol. X, No. VI, June, 1913, pp. 241–8, with a portrait, Pl. IX); for obituary see op. cit., April, 1915, p. 192.

was gladly accepted by the British Museum. From that time until nearly the end of his life he made continual additions to the Dawson Collection, as it was named by the Museum, where it now occupies a conspicuous position. The last noteworthy accession to it was the finest known specimen of the Wealden ganoid fish, *Lepidotus mantelli*. On the death of Mr. Beckles in 1890, Mr. Dawson also gave much help to the British Museum in labelling the collection of Wealden fossils which was acquired from that gentleman's executors.

Among the Wealden Dinosaurian remains discovered by Mr. Dawson, Mr. Lydekker recognized three new species of *Iguanodon*, of which one was named *I. dawsoni*. Among his later discoveries was the first tooth of a Wealden mammal, *Plagiaulax dawsoni*. He obtained this specimen from one of the fine pebbly bone-beds which occur in different horizons of the Wealden series. He subsequently encouraged two French students at the Hastings Jesuit College, Fathers Teilhard de Chardin and Pelletier, to examine these bone-beds more thoroughly, and they succeeded in finding a second form of mammalian tooth, *Dipriodon valdensis*, besides numerous rare teeth of reptiles and fishes. Mr. Dawson was also the stimulating friend of Mr. Philip Rufford, who made the great collection of Wealden plants now in the British Museum.

While interested chiefly in the fossils of the Wealden formation, Mr. Dawson also paid much attention to its more purely geological features, and he made one important investigation of the natural gas at Heathfield, which he described to the Geological Society in 1898. He also exhibited zincblende from the Wealden and Purbeck beds to the same Society in 1913.

Mr. Dawson's most important archæological work culminated in his publication of the two handsome volumes on the *History of Hastings Castle* in 1909. His interest in geology, however, gradually led him to turn to prehistoric archæology, and during his later years he searched most persistently the superficial deposits of Southern Sussex. His ultimate success was his recognition of the great antiquity of the Piltdown gravel, and his discovery in this deposit of the skull and mandible of the oldest known type of man, *Eoanthropus dawsoni*, which was described to the largest meeting of the Geological Society ever assembled in December, 1912. The story of this discovery, which was not altogether accidental but the outcome of logical reasoning, is now so well known and has been so often repeated that it need not be further detailed here.

Mr. Dawson made few contributions to geological literature—he preferred to hand over his specimens to experts who had made a special study of the groups to which they belonged. He published only one paper in the Geological Magazine, on "Dene Holes, Ancient and Modern" (1898, p. 293), concluding that they were all mines. His only contributions to the Geological Society's Quarterly Journal were those on Natural Gas and the Piltdown Man already mentioned. His last paper, read to the Anthropological Institute in 1915, was an ingenious comparison between the shapes of the so-called 'Eoliths' of tabular flint and the shapes of diminutive splinters obtained from the hexagonal columns of starch. He maintained that tabular flint

had an imperfect hexagonal structure, and that accidental fractures must produce the shapes found in 'Eoliths'.

Mr. Dawson was a most versatile student, and during the beginning of his last illness was investigating a case of the development of incipient horns in a cart-horse. He had a restless mind, ever alert to note anything unusual; and he was never satisfied until he had exhausted all means to solve and understand any problem which presented itself. He was a delightful colleague in scientific research, always cheerful, hopeful, and overflowing with enthusiasm. The premature loss of his inspiring and genial presence is indeed a great sorrow to his large circle of devoted friends. A. S. W.

ROBERT JOHN LECHMERE GUPPY,

Corresponding Member of the Zoological Society of London and of the New York and Philadelphia Academies of Science.

BORN AUGUST 15, 1836. DIED AUGUST 5, 1916.

WE deeply regret to announce the death of Robert John Lechmere Guppy, in the Island of Trinidad, on August 5, 1916, who was within a few days of completing the 80th year of his age. The deceased was born in London in 1836, his father being the Hon. R. Guppy, M.A., Barrister-at-law, and for many years the Mayor of San Fernando, Trinidad. He qualified for a Civil Engineer, and afterwards travelled through Australia, Tasmania, and New Zealand. On returning he joined his family at Trinidad and became engaged in the construction of the Cipero Railway, subsequently entering the Colonial Secretary's office, and in 1868 was appointed to the important position of Chief Inspector of Schools, which he held until retirement in 1891. He was an ardent student of natural history and foremost in supporting the scientific societies of his island home, having been president of the Scientific Association of Trinidad and the first elected presiding officer of the Royal Victoria Institute Board. He was particularly interested in the Marine Mollusca, and was instrumental in obtaining for the British Museum the second largest example of a living species of *Pleurotomaria* known to conchologists, having a height of 150 millimetres. The shell was obtained from off the Island of Tobago, and was described by Guppy in a locally published journal.

Mr. Guppy's scientific labours will always be associated with his investigations on the geology and palæontology of Trinidad and other regions of the West Indies. Until his researches began the only information on the geology of Trinidad was obtainable from Wall and Sawkins' "Report" of 1860, published by the Geological Survey of England, the palæontological portion of which was furnished by the late R. Etheridge, F.R.S., who regarded the Tertiary fossils as belonging probably to the Miocene period. Guppy's first papers referred to the Foraminiferal beds of San Fernando, containing numerous Orbitoides and other forms, as well as Brachiopods, Echinoids, and Crustacea, which were described and figured and assigned to the older Miocene. It was found that these fossils bore resemblances to those from the Farallon rock which enabled both sets